No.

The Integrated Master Plan Study for Dzongkhag-wise Electrification in Bhutan

Final Report

Executive Summary

October 2005

Japan International Cooperation Agency

Economic Development Department

ED
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Preface

In response to a request from Kingdom of Bhutan, the Government of Japan decided to conduct The Integrated Master Plan Study for Dzongkhag-wise Electrification in Bhutan and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team led by Mr. Tomoyasu Fukuchi, Nippon Koei Co., Ltd. to Bhutan six times from December 2003 to November 2005.

The study team held discussions with the officials concerned of the Royal Government of Bhutan and conducted a series of field surveys. After returning to Japan, the study team carried out further studies and compiled the final results in this report.

I hope this report will be utilized for contributing to Dzongkhag-wise Electrification of Bhutan and to the promotion of amity between our two countries.

I also express my sincere appreciation to the officials concerned of the Royal Government of Bhutan for their close cooperation throughout the study.

November 2005

Tadashi IZAWA
Vice President
Japan International Cooperation Agency

November 2005

Mr. Tadashi IZAWA
Vice President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Izawa,

Letter of Transmittal

We are pleased to submit the Final Report on completion of the Integrated Master Plan Study for Dzongkhag-wise Electrification in Bhutan. The report consolidates the achievements of collaborative work between related organizations in Bhutan and the study team over the past two years.

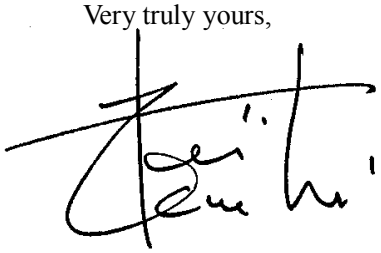
The Final Report has a role as an action plan for the Royal Government of Bhutan to materialize their ambitious goal of "electricity for all by 2020". From the other point of view, the master plan shows how to derive a rational balance between two targets having potentially divergent objectives: environmental conservation and economic efficiency in the rural development. The balance point was planned to be the expansion of the distribution lines to 90% of the non-electrified rural households and providing off-grid electricity for the remaining 10%.

As for environmental consideration, the concept of Strategic Environmental Assessment was incorporated. The level of consideration given to the environment was significantly greater than had ever been done in the master plan stage.

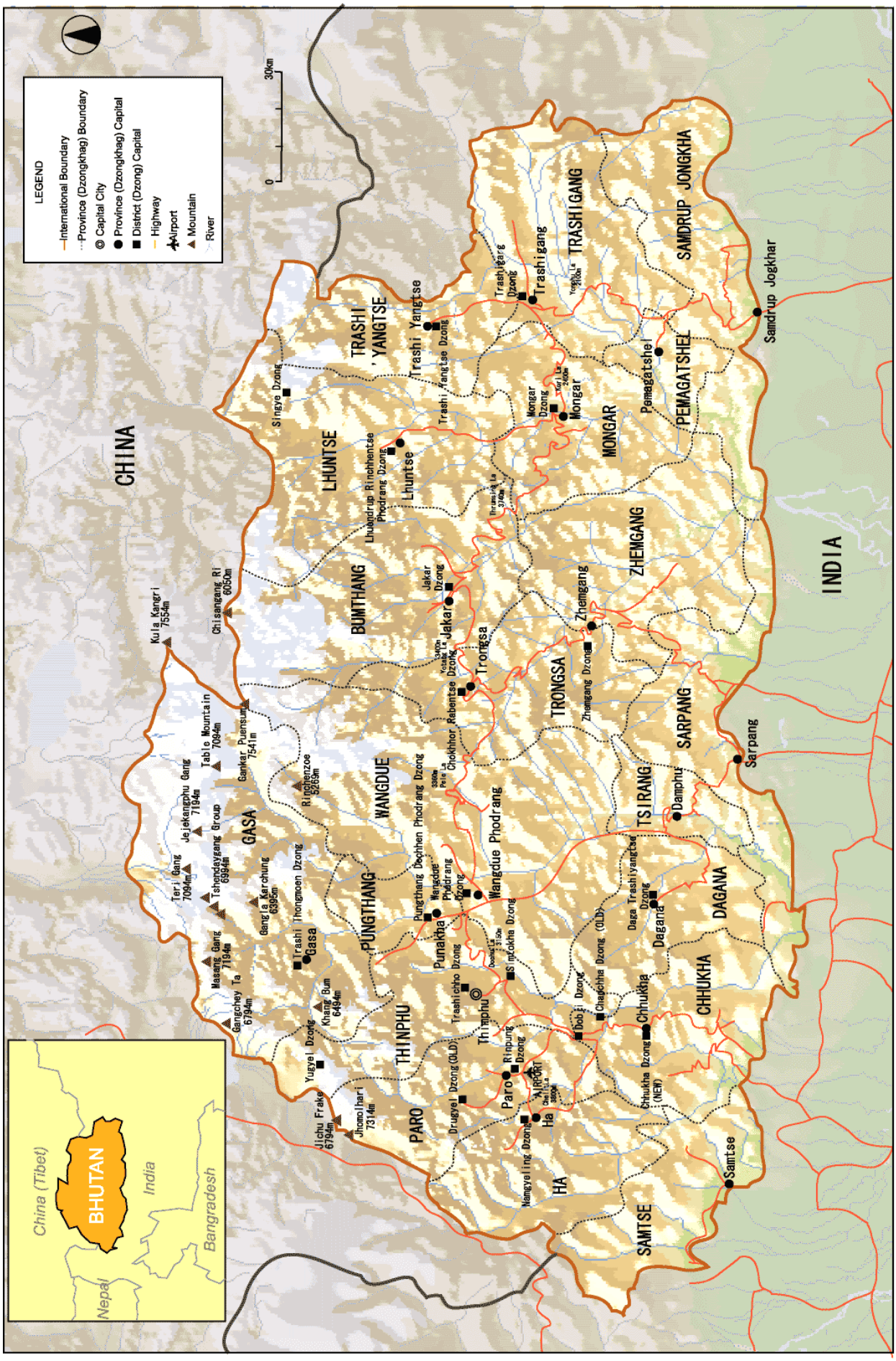
In this study, technology transfer to the Bhutanese counterparts was performed diligently and with a sense of purpose. Technological innovation in the field of new energies, including renewable energy, is proceeding rapidly, and improvement in the economic efficiency of these technologies is accelerating. In the future, every time the master plan is reviewed, the balance point will be shifted towards the environmentally friendly side. The technology transfer was conducted so that the Bhutanese counterparts can review the master plan and modify the balance point by themselves. We hope that the master plan will continue to be modified toward the goals of Bhutan.

Finally, we would like to express sincere appreciation to the Bhutanese counterparts and other organizations in the Royal Government of Bhutan for their dedicated cooperation. In addition, we sincerely appreciate the support and guidance of JICA Head Office, JICA Bhutan Office and the JICA India Office. Furthermore, the study team would like to thank JBIC, the Embassy of Japan in India, and ADB for their cooperation and assistance toward the realization of the master plan.

Very truly yours,



Tomoyasu FUKUCHI
Team Leader
The Integrated Master Plan Study for
Dzongkhag-wise Electrification in Bhutan



Location Map of Study Area (Bhutan)

THE INTEGRATED MASTER PLAN STUDY
FOR DZONGKHAG-WISE ELECTRIFICATION
IN BHUTAN

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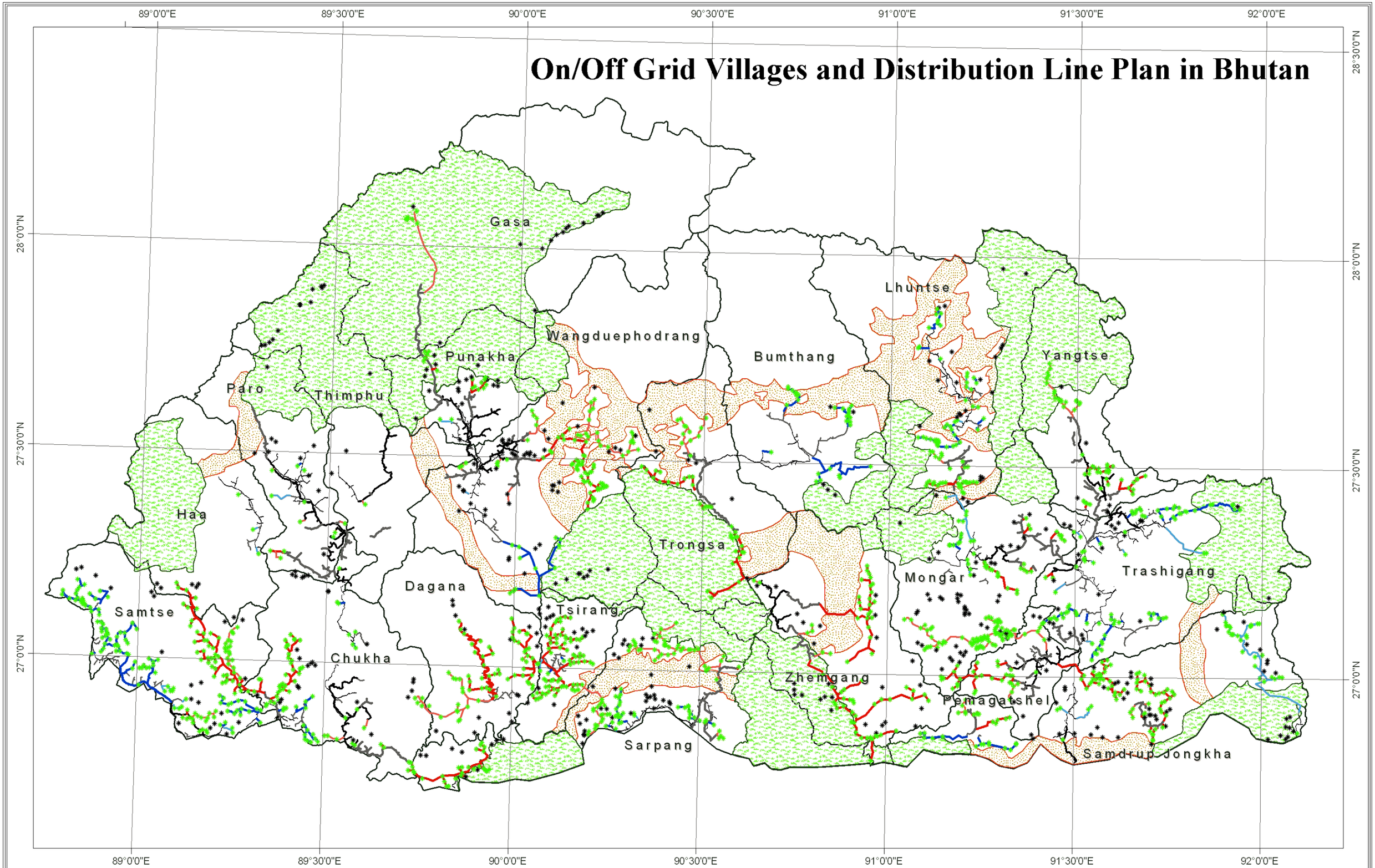
PROFILES OF DZONGKHAG-WISE MASTER PLAN

On/Off Grid Villages and Distribution Line Plan in Bhutan



JICA Study Team

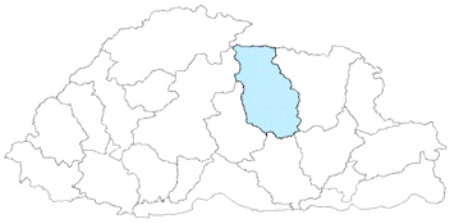
THE INTEGRATED MASTER PLAN STUDY FOR DZONGKHAG-WISE ELECTRIFICATION IN BHUTAN

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	-			
2	Name of Dzongkhag	**BHUTAN** **(All 20 Dzongkhags)**			
3	Nos of Non-electrified Village	in 2003 (Actual):	1,717		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	30,298		
		in 2007 (Forecasted):	**33,259**		
		in 2012 (Forecasted):	37,217		
		in 2017 (Forecasted):	41,469		
		in 2020 (Forecasted):	44,218		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	858	(50.0%)	
		11th FYP (2012-2017):	410	(23.9%)	
		TOTAL	1,268	(73.8%)	
6	Nos of Villages to be electrified by Off-grid		449	(26.2%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	21,519	(64.7%)	
		11th FYP (2012-2017):	7,819	(23.5%)	
		TOTAL	29,338	(88.2%)	
8	Nos of Household to be electrified by Off-grid*		3,918	(11.8%)	
9	Investment for On-grid (x1000 Nu.)	10th FYP (2007-2012):	2,214,793	49,218	(US$1,000)
		11th FYP (2012-2017):	996,217	22,138	(US$1,000)
		TOTAL	3,211,010	71,356	(US$1,000)
10	Investment for off-grid (x1000 Nu.)		114,407	2,542	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	1,579,952		
		11th FYP (2012-2017):	741,885		
		TOTAL	2,321,837		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	55.2%		
		On-grid in 2012:	84.0%		
		On-grid in 2017:	94.7%		
		Off-grid in 2017:	5.3%		
		TOTAL in 2017:	100.0%		

*: Numbers are based on the foreasted household number in 2007.

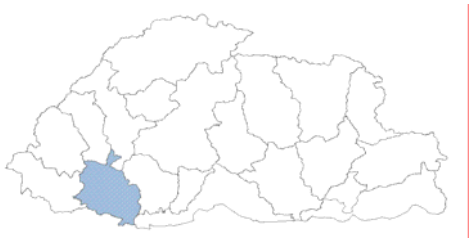
Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**A**			
2	Name of Dzongkhag	**Bumthang**			
3	Nos of Non-electrified Village	in 2003 (Actual):	35		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	446		
		in 2007 (Forecasted):	**494**		
		in 2012 (Forecasted):	553		
		in 2017 (Forecasted):	630		
		in 2020 (Forecasted):	681		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	30	(85.7%)	
		11th FYP (2012-2017):	0	(0.0%)	
		TOTAL	30	(85.7%)	
6	Nos of Villages to be electrified by Off-grid		5	(14.3%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	475	(96.2%)	
		11th FYP (2012-2017):	0	(0.0%)	
		TOTAL	475	(96.2%)	
8	Nos of Household to be electrified by Off-grid*		19	(3.8%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	64,605	1,436	(US$1,000)
		11th FYP (2012-2017):	0	0	(US$1,000)
		TOTAL	64,605	1,436	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		624	14	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	64,454		
		11th FYP (2012-2017):	0		
		TOTAL	64,454		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	75.4%		
		On-grid in 2012:	99.1%		
		On-grid in 2017:	99.1%		
		Off-grid in 2017:	0.9%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By the target year of 2020, 30 villages, corresponding 86% of non-electrified villages, are planned to be connected to the grid. This will provide on-grid electricity to 653 households, which is 96% of the non-electrified households. All grid extensions are to be implemented 10th FYP. There will be 28 off-grid households 5 villages.
The total route length of the planned 11 kV medium voltage line is 64 km. The electricity will be supplied from Jakar and the proposed Garpang transmission substations. Since 8 km of the feeder MPA11F1 will pass through a biological corridor, covered conductors will be installed fro this section of the feeder.
The on-grid electrification cost is 65 million Nu.and that of off-grid is 0.62 million Nu.
The on-grid electrification percentage is projected to be 75% in 2007, and will reach 99% in 10th FYP. The remaining 1% will be off-grid.

*: Numbers are based on the foreasted household number in 2007.

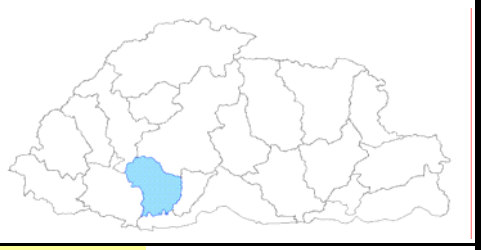
Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**B**			
2	Name of Dzongkhag	**Chukha**			
3	Nos of Non-electrified Village	in 2003 (Actual):	108		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	1,814		
		in 2007 (Forecasted):	**1,985**		
		in 2012 (Forecasted):	2,244		
		in 2017 (Forecasted):	2,536		
		in 2020 (Forecasted):	2,699		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	63	(58.3%)	
		11th FYP (2012-2017):	15	(13.9%)	
		TOTAL	78	(72.2%)	
6	Nos of Villages to be electrified by Off-grid		30	(27.8%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	1,422	(71.6%)	
		11th FYP (2012-2017):	279	(14.1%)	
		TOTAL	1,701	(85.7%)	
8	Nos of Household to be electrified by Off-grid*		284	(14.3%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	122,292	2,718	(US$1,000)
		11th FYP (2012-2017):	31,442	699	(US$1,000)
		TOTAL	153,734	3,416	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		8,626	192	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	94,186		
		11th FYP (2012-2017):	31,376		
		TOTAL	125,562		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	56.4%		
		On-grid in 2012:	87.6%		
		On-grid in 2017:	93.8%		
		Off-grid in 2017:	6.2%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, 2,312 households in 78 villages, equivalent to 72% of the total number of non-electrified villages, will be connected the grid. A total of 387 households in 30 non-electrified villages will be off-grid.
The total route length of the planned medium voltage line is 126 km, with 74% being 33 kV and the rest being 11 kV lines. 94 km will be constructed in 10th FYP and 31 km will be constructed in 11th FYP. There are no environmentally protected areas in this Dzongkhag.
The on-grid electrification cost in 10th FYP is 122 million Nu., and that of 11th FYP is 32 million Nu. The off-grid investment is 8.7 million Nu.
The on-grid electrification percentage in 2007 will be 56%, and will increase to 88% in 10th FYP and 94% in 11th FYP. The remaining 6% will be off-grid.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**C**			
2	Name of Dzongkhag	**Dagana**			
3	Nos of Non-electrified Village	in 2003 (Actual):	83		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	2,121		
		in 2007 (Forecasted):	**2,360**		
		in 2012 (Forecasted):	2,692		
		in 2017 (Forecasted):	3,073		
		in 2020 (Forecasted):	3,313		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	48	(57.8%)	
		11th FYP (2012-2017):	17	(20.5%)	
		TOTAL	65	(78.3%)	
6	Nos of Villages to be electrified by Off-grid		18	(21.7%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	1,731	(73.3%)	
		11th FYP (2012-2017):	429	(18.2%)	
		TOTAL	2,160	(91.5%)	
8	Nos of Household to be electrified by Off-grid*		200	(8.5%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	191,245	4,250	(US$1,000)
		11th FYP (2012-2017):	57,737	1,283	(US$1,000)
		TOTAL	248,982	5,533	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		6,241	139	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	131,861		
		11th FYP (2012-2017):	42,850		
		TOTAL	174,711		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	34.2%		
		On-grid in 2012:	92.2%		
		On-grid in 2017:	93.3%		
		Off-grid in 2017:	5.9%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

On-grid connection to 3,033 households in 64 non-electrified villages, equivalent to 78% of the total of number of non-electrified villages, is the plan for 2020. This includes 545 households (forecast for the year 2020) connected to the existing 6.6 kV lines, for which power is currently supplied by a small hydropower. The 6.6 kV lines will be replaced with 33 kV lines. In addition, 18 villages with a total of 280 households will be off-grid.

The total route length of the planned 33 kV medium voltage line is 175 km . For Dagana Dzongkhag, 132 km will be constructed in 10th FYP, including 45 km of existing 6.6 kV line replacement for the Dagana Small Hydropower. The remaining 43 km will be extended in 11th FYP. There are no environmentally protected areas in this Dzongkhag. Electricity will be supplied from the proposed Goshi substation, except for Lajab, Tsangkha and Drugelgang Gewog in the eastern areas, which will be supplied from Tsirang.

Total on-grid electrification cost in 10th FYP is 191 million Nu., and that for 11th FYP is 58 million Nu. Total investment for on-grid electrification is 249 million Nu. and the off-grid investment is 6.3 million Nu.

The on-grid electrification percentage in 2007 is projected to be relatively low at 34%. However, this will rise to 92% in 10th FYP and 93% in 11th FYP. The off-grid electrification will be 7%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**D**			
2	Name of Dzongkhag	**Gasa**			
3	Nos of Non-electrified Village	in 2003 (Actual):	21		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	331		
		in 2007 (Forecasted):	**362**		
		in 2012 (Forecasted):	403		
		in 2017 (Forecasted):	448		
		in 2020 (Forecasted):	476		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	0	(0.0%)	
		11th FYP (2012-2017):	7	(33.3%)	
		TOTAL	7	(33.3%)	
6	Nos of Villages to be electrified by Off-grid		14	(66.7%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	0	(0.0%)	
		11th FYP (2012-2017):	184	(50.8%)	
		TOTAL	184	(50.8%)	
8	Nos of Household to be electrified by Off-grid*		178	(49.2%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	0	0	(US$1,000)
		11th FYP (2012-2017):	30,255	672	(US$1,000)
		TOTAL	30,255	672	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		5,193	115	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	0		
		11th FYP (2012-2017):	32,039		
		TOTAL	32,039		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	36.4%		
		On-grid in 2012:	36.4%		
		On-grid in 2017:	68.7%		
		Off-grid in 2017:	31.3%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

Half of the land in this Dzongkhag is covered by environmentally protected areas. By 2020, on-grid connection will be provided to 243 households in 7 villages, which is equivalent to 33% of the total number of non-electrified villages and 51% of the total of the non-electrified households. There is only one feeder, MPD33F1, which is 33 kV. This feeder, which will have a line length of 32 km, is planned to be extended in 11th FYP. Because of the environmental sensitivity of the route, feeder MPD33F1 was selected as the target for the draft TOR of an expected EIA study. This feeder extends in protected area and very steep mountains. Considering technical limitations anticipated especially over snow capped mountains during construction, as well as operation and maintenance and environmental issues, it would be recommended that small hydro be applied.

As for 33 kV lines come from Lobesa 66/33/11 kV substation, only one 33 kV circuit breaker is installed for the supply to Punakha, Gasa, and Wangduephodraung. Thus, installation of separate 33 kV circuit breaker in each Dzongkhag needs to be examined in the F/S stage to enhance the reliability.

Lunana Gewog will be all off-grid. There will be 233 off-grid households, equivalent to 49% of the non-electrified households in Gasa Dzongkhag. This is by far highest percentage of off-grid in the master plan for Bhutan.

On the on-grid electrification investment is 30 million Nu. and the off-grid investment will be 5.2 million Nu.

The on-grid electrification percentage in 2007 is projected to be 36%. No change will occur in 10th FYP. However, the percentage will increase to 69% in 11th FYP. Accordingly, it is preferred to prioritize the implementation of off-grid electrification from 10th FYP, taking Dzongkhag equity into account. At 31%, the planned off-grid electrification percentage is the highest in the nation.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**E**		
2	Name of Dzongkhag	**Haa**		
3	Nos of Non-electrified Village	in 2003 (Actual):	15	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	248	
		in 2007 (Forecasted):	**277**	
		in 2012 (Forecasted):	320	
		in 2017 (Forecasted):	368	
		in 2020 (Forecasted):	402	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	8	(53.3%)
		11th FYP (2012-2017):	2	(13.3%)
		TOTAL	10	(66.7%)
6	Nos of Villages to be electrified by Off-grid		5	(33.3%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	182	(65.7%)
		11th FYP (2012-2017):	26	(9.4%)
		TOTAL	208	(75.1%)
8	Nos of Household to be electrified by Off-grid*		69	(24.9%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	23,349	519 (US$1,000)
		11th FYP (2012-2017):	3,123	69 (US$1,000)
		TOTAL	26,472	588 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		2,229	50 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	20,925	
		11th FYP (2012-2017):	3,465	
		TOTAL	24,389	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	77.0%	
		On-grid in 2012:	92.1%	
		On-grid in 2017:	94.3%	
		Off-grid in 2017:	5.7%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

A total of 302 households in 10 villages, equivalent to 75% of non-electrified households and 67% of the non-electrified villages, will be connected to the grid by 2020. Half of the Dzongkhag is covered by a national park. However, there are no target non-electrified villages found in the area. In Haa Dzongkhag, 100 households, representing 30% of the non-electrified households in 5 villages, will have off-grid electrification.

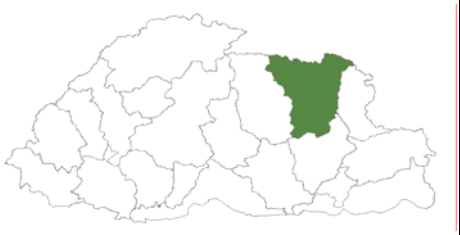
The total route length of the planned medium voltage line is 24 km. For this line, 85% will be 33 kV and the remaining 15% will be 11 kV. Most of this route (21 km) will be constructed in 10th FYP and 3 km will be constructed in 11th FYP. The starting point of the line will be Chukha in the southern part of the Dzongkhag, and the line will also pass through Samtse.

The on-grid electrification cost in 10th FYP is 23 million Nu., and that of 11th FYP is 3 million Nu., bringing the total to 27 million Nu. The off-grid investment will be 2.3 million Nu.

The on-grid electrification percentage in 2007 will be 77%, and increase to 92% in 10th FYP and 94% in 11th FYP. The remaining 6% is the off-grid electrification percentage.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**F**			
2	Name of Dzongkhag	**Luntse**			
3	Nos of Non-electrified Village	in 2003 (Actual):	103		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	1,377		
		in 2007 (Forecasted):	**1,477**		
		in 2012 (Forecasted):	1,619		
		in 2017 (Forecasted):	1,753		
		in 2020 (Forecasted):	1,852		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	46	(44.7%)	
		11th FYP (2012-2017):	27	(26.2%)	
		TOTAL	73	(70.9%)	
6	Nos of Villages to be electrified by Off-grid		30	(29.1%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	821	(55.6%)	
		11th FYP (2012-2017):	362	(24.5%)	
		TOTAL	1,183	(80.1%)	
8	Nos of Household to be electrified by Off-grid*		294	(19.9%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	96,182	2,137	(US$1,000)
		11th FYP (2012-2017):	49,451	1,099	(US$1,000)
		TOTAL	145,632	3,236	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		8,202	182	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	53,376		
		11th FYP (2012-2017):	34,379		
		TOTAL	87,755		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	44.1%		
		On-grid in 2012:	75.2%		
		On-grid in 2017:	88.9%		
		Off-grid in 2017:	11.1%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, 73 villages with 1,484 households, equivalent to 71% of the total number of non-electrified villages and 80% of the non-electrified households, will be connected the grid. Off-grid electrification will be provided to 368 households in 30 villages, which represents 29% of the non-electrified villages and 20% of non-electrified households.

The total route length of the planned medium voltage line is 88 km. For this route, 33% will be 33 kV lines and the remaining 67% will be 11 kV lines. Construction of 53 km will be completed in 10th FYP and 34 km will be constructed in 11th FYP. Many areas of the Dzongkhag are environmentally protected areas. This will require covered conductors being installed for a total of 3.2 km of the distribution line, of which 1.8 km will be constructed in 10th FYP.

Currently, 132 kV transmission line from Kilikhar (Mongar) to Tangmachu (Lhuntse) is charged at 33 kV and 33 kV source for Autsho is directly tapped from 132 kV line. It is needed to include the study for the construction of substations in F/S.

It is preferable to introduce off-grid electrification for villages in environmentally protected areas that are far from the planned distribution lines. Khoma Gewog is the priority location for off-grid electrification.

The on-grid electrification cost in 10th FYP is 96 million Nu., and that of 11th FYP is 49 million Nu., bringing the total to 145 million Nu.

The required off-grid investment will be 8 million Nu.

The on-grid electrification percentage in 2007 will be 44%, and increase to 75% in 10th FYP and 89% in 11th FYP. The off-grid electrification percentage will be 11%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**G**		
2	Name of Dzongkhag	**Mongar**		
3	Nos of Non-electrified Village	in 2003 (Actual):	183	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	2,662	
		in 2007 (Forecasted):	**2,865**	
		in 2012 (Forecasted):	3,172	
		in 2017 (Forecasted):	3,480	
		in 2020 (Forecasted):	3,686	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	44	(24.0%)
		11th FYP (2012-2017):	82	(44.8%)
		TOTAL	126	(68.9%)
6	Nos of Villages to be electrified by Off-grid		57	(31.1%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	1,057	(36.9%)
		11th FYP (2012-2017):	1,310	(45.7%)
		TOTAL	2,367	(82.6%)
8	Nos of Household to be electrified by Off-grid*		498	(17.4%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	119,282	2,651 (US$1,000)
		11th FYP (2012-2017):	172,939	3,843 (US$1,000)
		TOTAL	292,221	6,494 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		14,309	318 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	62,856	
		11th FYP (2012-2017):	111,164	
		TOTAL	174,019	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	51.0%	
		On-grid in 2012:	69.1%	
		On-grid in 2017:	91.5%	
		Off-grid in 2017:	8.5%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, 126 villages with 3,044 households, equivalent to 69% of the total number of non-electrified villages and 83% of the non-electrified households, will be connected the grid. There will be 642 off-grid households, which is the largest number of off-grid households in one Dzongkhag in Bhutan.
The total route length of the planned medium voltage line is 174 km. For this route, 80% will be 33 kV lines and the remaining 20% will be 11 kV lines. There will be 63 km of line constructed in 10th FYP and 111 km in 11th FYP.
Electricity is provided from Pemagatshel in the southern part of the Dzongkhag. The feeder that extends to Lhuntse includes 17 km in environmentally protected areas. This section of the line will use covered conductors.
The on-grid electrification cost in 10th FYP is 120 million Nu., and that of 11th FYP is 173 million Nu., bringing the total to 292 million Nu. The off-grid investment will be 14 million Nu.
The on-grid electrification percentage in 2007 will be 51%, and increase to 69% in 10th FYP and 91% in 11th FYP. The off-grid electrification percentage will be 9%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

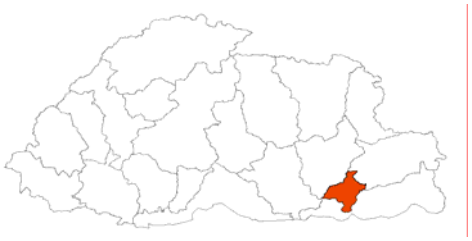
1	Dzongkhag Code	**H**		
2	Name of Dzongkhag	**Paro**		
3	Nos of Non-electrified Village	in 2003 (Actual):	22	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	162	
		in 2007 (Forecasted):	**174**	
		in 2012 (Forecasted):	196	
		in 2017 (Forecasted):	221	
		in 2020 (Forecasted):	234	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	5	(22.7%)
		11th FYP (2012-2017):	6	(27.3%)
		TOTAL	11	(50.0%)
6	Nos of Villages to be electrified by Off-grid		11	(50.0%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	57	(32.8%)
		11th FYP (2012-2017):	47	(27.0%)
		TOTAL	104	(59.8%)
8	Nos of Household to be electrified by Off-grid*		70	(40.2%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	5,447	121 (US$1,000)
		11th FYP (2012-2017):	8,735	194 (US$1,000)
		TOTAL	14,182	315 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		2,051	46 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	5,577	
		11th FYP (2012-2017):	12,297	
		TOTAL	17,874	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	96.0%	
		On-grid in 2012:	97.3%	
		On-grid in 2017:	98.4%	
		Off-grid in 2017:	1.6%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

Almost all the households in Paro (96%) will be electrified in 2007, as most already have electricity. By 2020, on-grid connection will be provided to 11 villages with 142 households, equivalent to 50% of non-electrified villages and 61% of non-electrified households. There will be 92 off-grid households.
The total route length of the planned medium voltage line is 18 km, of which 48% will be 33 kV lines and the remaining 17% will be 11 kV lines. For this route, 6 km will be constructed in 10th FYP and 12 km will be constructed in 11th FYP. There are some non-electrified villages in environmentally protected areas in the northern part of the Dzongkhag, and these will be off-grid.
The on-grid electrification cost in 10th FYP will be 5 million Nu., that of 11th FYP will be 9 million Nu., bringing the total to 14 million Nu. The off-grid investment will be 2 million Nu.

The on-grid electrification percentage in 2007 will be 96%, which is the highest in Bhutan. This is because most parts of the Dzongkhag are already connected to the grid. It will increase to 97% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2% by 2020.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**I**		
2	Name of Dzongkhag	**Pemaga-tshel**		
3	Nos of Non-electrified Village	in 2003 (Actual):	33	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	650	
		in 2007 (Forecasted):	**643**	
		in 2012 (Forecasted):	643	
		in 2017 (Forecasted):	643	
		in 2020 (Forecasted):	643	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	16	(48.5%)
		11th FYP (2012-2017):	10	(30.3%)
		TOTAL	26	(78.8%)
6	Nos of Villages to be electrified by Off-grid		7	(21.2%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	470	(73.1%)
		11th FYP (2012-2017):	125	(19.4%)
		TOTAL	595	(92.5%)
8	Nos of Household to be electrified by Off-grid*		48	(7.5%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	48,320	1,074 (US$1,000)
		11th FYP (2012-2017):	22,991	511 (US$1,000)
		TOTAL	71,311	1,585 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		1,070	24 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	31,521	
		11th FYP (2012-2017):	23,752	
		TOTAL	55,273	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	76.8%	
		On-grid in 2012:	93.8%	
		On-grid in 2017:	98.3%	
		Off-grid in 2017:	1.7%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, 26 villages with 595 households, equivalent to 79% of the total number of the non-electrified villages and 93% of the non-electrified households, will be connected the grid. The number of off-grid households will be 48.
The total route length of the planned 33 kV medium voltage line is 55 km. 32 km will be constructed in 10th FYP and the remaining 24 km will be constructed in 11th FYP. There are no environmentally protected areas in this Dzongkhag.
The on-grid electrification cost in 10th FYP is 48 million Nu., and that of 11th FYP is 23 million Nu., bringing the total to 71 million Nu. The off-grid investment will be one million Nu.
The on-grid electrification percentage in 2007 will be 77%. This will increase to 94% in 10th FYP and 98% in 11th FYP.
The off-grid electrification percentage will be 2%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**J**		
2	Name of Dzongkhag	**Punakha**		
3	Nos of Non-electrified Village	in 2003 (Actual):	35	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	263	
		in 2007 (Forecasted):	**275**	
		in 2012 (Forecasted):	294	
		in 2017 (Forecasted):	313	
		in 2020 (Forecasted):	331	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	15	(42.9%)
		11th FYP (2012-2017):	2	(5.7%)
		TOTAL	17	(48.6%)
6	Nos of Villages to be electrified by Off-grid		18	(51.4%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	167	(60.7%)
		11th FYP (2012-2017):	15	(5.5%)
		TOTAL	182	(66.2%)
8	Nos of Household to be electrified by Off-grid*		93	(33.8%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	21,812	485 (US$1,000)
		11th FYP (2012-2017):	3,211	71 (US$1,000)
		TOTAL	25,023	556 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		2,496	55 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	22,139	
		11th FYP (2012-2017):	5,426	
		TOTAL	27,565	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	88.6%	
		On-grid in 2012:	95.5%	
		On-grid in 2017:	96.1%	
		Off-grid in 2017:	3.9%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, 17 villages with 219 households, equivalent to 49% of the total number of non-electrified villages and 66% of the non-electrified households, will be connected the grid. The number of off-grid household will be 112.

The total route length of the planned medium voltage line is 25 km. For this route, 76% will be 33 kV lines and remaining 24% will be 11 kV lines. There will be 22 km constructed in 10th FYP and 3 km will be constructed in 11th FYP. In addition, 7 km of the distribution line passes through environmentally protected areas and covered conductors will be installed in this section. All of the line that is in the environmentally protected area will be constructed in 10th FYP.

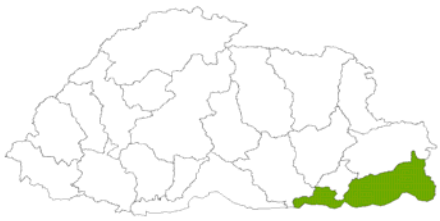
As for 33 kV lines come from Lobesa 66/33/11 kV substation, only one 33 kV circuit breaker is installed for the supply to Punakha, Gasa, and Wangduephodraung. Thus, installation of separate 33 kV circuit breaker in each Dzongkhag needs to be examined in the F/S stage to enhance the reliability.

The on-grid electrification cost in 10th FYP will be 22 million Nu., and that of 11th FYP will be 3 million Nu., bringing the total to 25 million Nu. The off-grid investment will be 2.5 million Nu.

The on-grid electrification percentage in 2007 will be 89%, which is the third highest in Bhutan. It will increase to 95.5% in 10th FYP and 96.2% in 11th FYP. The off-grid electrification percentage will be 4%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**K**			
2	Name of Dzongkhag	**Samdrup Jongkhar**			
3	Nos of Non-electrified Village	in 2003 (Actual):	177		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	3,573		
		in 2007 (Forecasted):	**3,837**		
		in 2012 (Forecasted):	4,200		
		in 2017 (Forecasted):	4,590		
		in 2020 (Forecasted):	4,842		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	83	(46.9%)	
		11th FYP (2012-2017):	45	(25.4%)	
		TOTAL	128	(72.3%)	
6	Nos of Villages to be electrified by Off-grid		49	(27.7%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	2,212	(57.7%)	
		11th FYP (2012-2017):	1,221	(31.8%)	
		TOTAL	3,433	(89.5%)	
8	Nos of Household to be electrified by Off-grid*		401	(10.5%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	203,489	4,522	(US$1,000)
		11th FYP (2012-2017):	173,691	3,860	(US$1,000)
		TOTAL	377,180	8,382	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		11,300	251	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	144,186		
		11th FYP (2012-2017):	106,173		
		TOTAL	250,358		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	31.2%		
		On-grid in 2012:	70.7%		
		On-grid in 2017:	92.8%		
		Off-grid in 2017:	7.2%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

There are 4,842 non-electrified households predicted for 2020, which is the second largest in Bhutan after Samtse. There are 4,335 households in 128 villages, equivalent to 72% of the total number of the non-electrified villages, that will be connected to the grid. The total route length of planned medium voltage lines is 250 km. Of this, 50% will be 33 kV lines and the remaining 68% will be 11kV lines. Lauri and Serthing Gewog in the northeastern part of the Dzongkhag will be supplied from India. In addition, 14 km of feeder MPK11F2-4 passes through a national park. This is the longest length of line in a protected area. In addition, the source identified for grid extension is from Daifam which receives electric supply from India and this supply is known for its poor reliability. Therefore, the feasibility study of micro hydro is recommended for not only provide reliable supply of electricity to the Shingkhar Lauri villages but can also feed back the Daifam villages by our own supply in the future.

The on-grid electrification cost in 10th FYP is 203 million Nu., and that of 11th FYP is 174 million Nu., bringing the total to 377 million Nu. The off-grid investment is 11 million Nu.

The on-grid electrification percentage in 2007 will be quite low at 31%. However, it will become 71% in 10th FYP and 93% in 11th FYP. The off-grid electrification percentage will be 7%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**L**			
2	Name of Dzongkhag	**Samtse**			
3	Nos of Non-electrified Village	in 2003 (Actual):	181		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	4,318		
		in 2007 (Forecasted):	**4,765**		
		in 2012 (Forecasted):	5,366		
		in 2017 (Forecasted):	6,088		
		in 2020 (Forecasted):	6,541		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	119	(65.7%)	
		11th FYP (2012-2017):	41	(22.7%)	
		TOTAL	160	(88.4%)	
6	Nos of Villages to be electrified by Off-grid		21	(11.6%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	3,658	(76.8%)	
		11th FYP (2012-2017):	852	(17.9%)	
		TOTAL	4,510	(94.6%)	
8	Nos of Household to be electrified by Off-grid*		255	(5.4%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	280,368	6,230	(US$1,000)
		11th FYP (2012-2017):	71,205	1,582	(US$1,000)
		TOTAL	351,573	7,813	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		7,756	172	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	243,224		
		11th FYP (2012-2017):	57,265		
		TOTAL	300,488		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	39.5%		
		On-grid in 2012:	85.9%		
		On-grid in 2017:	96.8%		
		Off-grid in 2017:	3.2%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, 6,193 households in 160 villages, equivalent to 88% of the total number of the non-electrified villages and 95% of the non-electrified households, will be on-grid. This is the largest number of on-grid houses in a Dzongkhag in Bhutan. The number of off-grid households will be 348.

The total route length of the planned medium voltage lines is 292 km. For this route, 45% of the lines are 33 kV and the remainders are 11kV lines. Most of the route (234 km) is planned to be extended in 10th FYP, and the remaining 57 km will be extended in 11th FYP. There route does not pass through any environmentally protected areas.

Mayona, Dungtoe, Dorokha, Denchhukha and Tading Gewogs in the eastern part of the Dzongkhag are to be supplied from Chukha. Bara and Tendu Gewogs in the northwestern part of the Dzongkhag are to be supplied from Jaldhaka substation in India. This will require installation of two voltage regulators and replacement of 20 km of existing lines. As the demand and characteristics of the lines in India is not clear, it is needed that the design be examined measuring the voltage at the receiving point from India.

The on-grid electrification cost in 10th FYP is 280 million Nu., and that in 11th FYP is 71 million Nu., bringing the total to 352 million Nu. The off-grid investment will be 8 million Nu.

The on-grid electrification percentage in 2007 will be 40%. It will increase to 86% in 10th FYP and 97% in 11th FYP. The off-grid electrification percentage will be 3%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**M**		
2	Name of Dzongkhag	**Sarpang**		
3	Nos of Non-electrified Village	in 2003 (Actual):	162	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	2,570	
		in 2007 (Forecasted):	**2,993**	
		in 2012 (Forecasted):	3,457	
		in 2017 (Forecasted):	3,999	
		in 2020 (Forecasted):	4,346	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	59	(36.4%)
		11th FYP (2012-2017):	64	(39.5%)
		TOTAL	123	(75.9%)
6	Nos of Villages to be electrified by Off-grid		39	(24.1%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	1,385	(46.3%)
		11th FYP (2012-2017):	1,223	(40.9%)
		TOTAL	2,608	(87.1%)
8	Nos of Household to be electrified by Off-grid*		385	(12.9%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	123,481	2,744 (US$1,000)
		11th FYP (2012-2017):	134,572	2,990 (US$1,000)
		TOTAL	258,053	5,735 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		12,370	275 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	92,646	
		11th FYP (2012-2017):	105,796	
		TOTAL	198,443	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	41.2%	
		On-grid in 2012:	68.4%	
		On-grid in 2017:	92.4%	
		Off-grid in 2017:	7.6%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, there will be 3,791 on-grid electrified households in 123 villages, which is equivalent to 76% of the total of the non-electrified villages and 87% of non-electrified household. The number of off-grid households will be 555, which is the second largest number for a Dzongkhag.

The total route length of the planned medium voltage lines is 198 km. For this route, 82% of the lines will be 33 kV and the remaining lines will be 11kV. 92 km is planned to be extended in 10th FYP and 106 km is planned to be extended in 11th FYP. The electricity needs of Lhamnozinkha and Michula Gewogs are currently supplied by diesel generators. These Gewogs have been prioritized for 10th FYP implementation to save the cost diesel fuel. Lhamozinkha, Deorali, and Nichula Gewogs will be supplied from Chukha, while Senge and Hiley Gewogs will be supplied from Tsirang. Belkhola, Larpani and Hiley Gewogs will be supplied from the Golephu substation, and an installation of voltage regulator is required for these areas. In addition, currently, there is no 33 kV source at Gelephu Substation. Therefore, it needs to examine to install either 132/33 or 66/33kV transformer at the substation in the F/S stage.

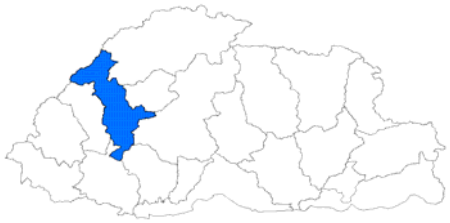
Four (4) feeders go through environmentally protected areas and these lines will have covered conductors within the protected areas. The total length of the lines in the protected areas is 32 km. Of this, 11.1 km is planned to be implemented in 10th FYP.

The on-grid electrification cost in 10th FYP is 123 million Nu., and that in 11th FYP is 134 million Nu., bringing the total to 258 million Nu. The off-grid investment will be 12 million Nu.

The on-grid electrification percentage in 2007 will be 41%. This will increase to 68% in 10th FYP and 92% in 11th FYP. The off-grid electrification percentage will be 8%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**N**			
2	Name of Dzongkhag	**Thimphu**			
3	Nos of Non-electrified Village	in 2003 (Actual):	16		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	132		
		in 2007 (Forecasted):	**135**		
		in 2012 (Forecasted):	146		
		in 2017 (Forecasted):	152		
		in 2020 (Forecasted):	157		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	0	(0.0%)	
		11th FYP (2012-2017):	1	(6.3%)	
		TOTAL	1	(6.3%)	
6	Nos of Villages to be electrified by Off-grid		15	(93.8%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	0	(0.0%)	
		11th FYP (2012-2017):	14	(10.4%)	
		TOTAL	14	(10.4%)	
8	Nos of Household to be electrified by Off-grid*		121	(89.6%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	0	0	(US$1,000)
		11th FYP (2012-2017):	1,604	36	(US$1,000)
		TOTAL	1,604	36	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		3,143	70	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	0		
		11th FYP (2012-2017):	1,482		
		TOTAL	1,482		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	93.0%		
		On-grid in 2012:	93.0%		
		On-grid in 2017:	93.7%		
		Off-grid in 2017:	6.3%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, just 16 households in one village, equivalent to 6% of the total of the non-electrified villages, will be on-grid. The total route length of the planned 33 kV medium voltage line is only 1 km. No village will be connected to the grid in 10th FYP and the 14 households will be connected in 11th FYP. 141 households in 15 villages will be off-grid.

The on-grid electrification cost in 11th FYP is 1.6 million Nu. and that of the off-grid electrification is 3.2 million Nu.

The on-grid electrification percentage in 2007 will be as much as 93%, as almost all the areas are already electrified. It will be the same in 10th FYP and finally increase to 94% in 11th FYP. The off-grid electrification percentage will be 6%.

*: Numbers are based on the foreasted household number in 2007.

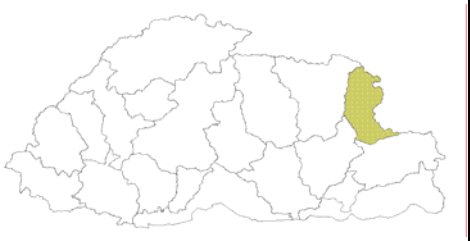
Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**O**			
2	Name of Dzongkhag	**Trashigang**			
3	Nos of Non-electrified Village	in 2003 (Actual):	105		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	2,087		
		in 2007 (Forecasted):	**2,206**		
		in 2012 (Forecasted):	2,370		
		in 2017 (Forecasted):	2,553		
		in 2020 (Forecasted):	2,663		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	67	(63.8%)	
		11th FYP (2012-2017):	15	(14.3%)	
		TOTAL	82	(78.1%)	
6	Nos of Villages to be electrified by Off-grid		23	(21.9%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	1,606	(72.8%)	
		11th FYP (2012-2017):	444	(20.1%)	
		TOTAL	2,050	(92.9%)	
8	Nos of Household to be electrified by Off-grid*		156	(7.1%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	172,827	3,841	(US$1,000)
		11th FYP (2012-2017):	46,825	1,041	(US$1,000)
		TOTAL	219,653	4,881	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		4,279	95	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	102,740		
		11th FYP (2012-2017):	30,457		
		TOTAL	133,197		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	74.8%		
		On-grid in 2012:	93.1%		
		On-grid in 2017:	98.2%		
		Off-grid in 2017:	1.8%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, there will be 82 villages with 2,471 households connected to the grid. This is equivalent to 78% of the total number of non-electrified villages and 93% of non-electrified households. The number of off-grid households will be 192.
The total route length of the planned 11 kV medium voltage line is 133 km. Of this, 102 km (97%) will be constructed in 10th FYP and 31 km will be constructed in 11th FYP. The 17 households in Merak Gewog will be supplied from Samdrup Jongkhar.
An ABS will be installed in Sakten and Kangpara Gewogs. Lines in Sakten and Merak Gewogs pass through environmentally protected areas and will require covered conductors to be used in these areas Feeder MPO11F1-3 will be expanded in 10th FYP and there will be 18 km within protected areas.
One option for MPO11F1-3 is to apply 33 kV system instead of change the feeder from 11 kV system with voltage regulator. There is a technical merit for 33 kV including reduction of power loss, however, 11 kV has a cost merit. It is recommended to conduct additional examination from overall perspective in a feasibility study.
The on-grid electrification cost in 10th FYP is 173 million Nu., and that in 11th FYP is 48 million Nu., bringing the total to 220 million Nu. The off-grid investment is 4 million Nu.
The on-grid electrification percentage in 2007 will be 75%. It will increase to 93% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2%.

*: Numbers are based on the foreasted household number in 2007.

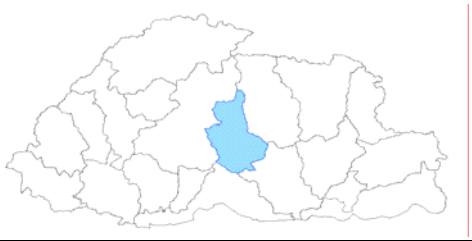
Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**P**			
2	Name of Dzongkhag	**Yangtse**			
3	Nos of Non-electrified Village	in 2003 (Actual):	56		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	1,157		
		in 2007 (Forecasted):	**1,262**		
		in 2012 (Forecasted):	1,407		
		in 2017 (Forecasted):	1,570		
		in 2020 (Forecasted):	1,678		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	31	(55.4%)	
		11th FYP (2012-2017):	20	(35.7%)	
		TOTAL	51	(91.1%)	
6	Nos of Villages to be electrified by Off-grid		5	(8.9%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	874	(69.3%)	
		11th FYP (2012-2017):	353	(28.0%)	
		TOTAL	1,227	(97.2%)	
8	Nos of Household to be electrified by Off-grid*		35	(2.8%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	90,770	2,017	(US$1,000)
		11th FYP (2012-2017):	51,674	1,148	(US$1,000)
		TOTAL	142,444	3,165	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		1,025	23	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	36,694		
		11th FYP (2012-2017):	28,571		
		TOTAL	65,265		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	59.3%		
		On-grid in 2012:	87.5%		
		On-grid in 2017:	98.9%		
		Off-grid in 2017:	1.1%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, there will be 51 villages with the households of 1,632 connected to the grid. This is equivalent to 91% of the total number of the non-electrified villages and 97% of the non-electrified households. A total of 46 households will be off-grid. The total route length of the planned 33 kV medium voltage line is 65 km. All electricity will be supplied from the Trashigang substation. There will be 37 km of line constructed in 10th FYP and 29 km constructed in 11th FYP. Covered conductors will be installed for 14 km of the distribution line, where it passes through environmentally protected areas.
The on-grid electrification cost in 10th FYP will be 91 million Nu., and that in 11th FYP will be 52 million Nu., bringing the total to 142 million Nu. The off-grid investment will be one million Nu.
The on-grid electrification percentage in 2007 will be 59%. It will increase to 87% in 10th FYP and 99% in 11th FYP. The off-grid electrification percentage will be only 1%.

*: Numbers are based on the foreasted household number in 2007.

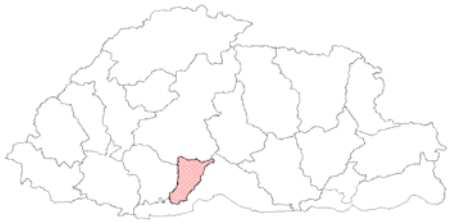
Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**Q**		
2	Name of Dzongkhag	**Trongsa**		
3	Nos of Non-electrified Village	in 2003 (Actual):	49	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	860	
		in 2007 (Forecasted):	**961**	
		in 2012 (Forecasted):	1,115	
		in 2017 (Forecasted):	1,278	
		in 2020 (Forecasted):	1,404	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	33	(67.3%)
		11th FYP (2012-2017):	11	(22.4%)
		TOTAL	44	(89.8%)
6	Nos of Villages to be electrified by Off-grid		5	(10.2%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	706	(73.5%)
		11th FYP (2012-2017):	223	(23.2%)
		TOTAL	929	(96.7%)
8	Nos of Household to be electrified by Off-grid*		32	(3.3%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	99,236	2,205 (US$1,000)
		11th FYP (2012-2017):	36,591	813 (US$1,000)
		TOTAL	135,827	3,018 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		1,092	24 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	68,650	
		11th FYP (2012-2017):	26,991	
		TOTAL	95,641	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	44.4%	
		On-grid in 2012:	85.3%	
		On-grid in 2017:	98.1%	
		Off-grid in 2017:	1.9%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, there will be 44 villages with 1,355 households connected to the grid. This is equivalent to 90% of the total number of non-electrified villages and 97% of the non-electrified households. There will be 49 off-grid households.
The total route length of the planned 33 kV medium voltage line is 96 km. Electricity will be supplied from the Trongsa substation. There will be 69 km of line constructed in 10th FYP and 27 km will be constructed in 11th FYP.
Three feeders pass through environmentally protected areas and covered conductors will be required where this occurs. There are 27 km (68% of total length) in protected areas. All of these lines will be constructed in 10th FYP.
The on-grid electrification cost in 10th FYP is 100 million Nu., and that of 11th FYP is 37 million Nu., bringing the total to 136 million Nu. The off-grid investment will be 1.1 million Nu.
The on-grid electrification percentage in 2007 will be 44%. It will increase to 85% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**R**		
2	Name of Dzongkhag	**Tsirang**		
3	Nos of Non-electrified Village	in 2003 (Actual):	86	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	2,186	
		in 2007 (Forecasted):	**2,594**	
		in 2012 (Forecasted):	3,064	
		in 2017 (Forecasted):	3,432	
		in 2020 (Forecasted):	3,686	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	69	(80.2%)
		11th FYP (2012-2017):	1	(1.2%)
		TOTAL	70	(81.4%)
6	Nos of Villages to be electrified by Off-grid		16	(18.6%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	2,423	(93.4%)
		11th FYP (2012-2017):	30	(1.2%)
		TOTAL	2,453	(94.6%)
8	Nos of Household to be electrified by Off-grid*		141	(5.4%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	234,916	5,220 (US$1,000)
		11th FYP (2012-2017):	3,182	71 (US$1,000)
		TOTAL	238,099	5,291 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		4,413	98 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	117,228	
		11th FYP (2012-2017):	3,623	
		TOTAL	120,851	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	23.8%	
		On-grid in 2012:	95.0%	
		On-grid in 2017:	95.9%	
		Off-grid in 2017:	4.1%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, there will be 70 villages with 3,488 households connected to the grid. This is equivalent to 81% of the total number of non-electrified villages and 95% of the non-electrified households. There will be 198 off-grid households.
The total route length of the planned medium voltage line is 121 km. For this route, 95% of the lines will be 33 kV supplied from the Dhajay substation. The remaining 5% will be 11kV lines. The route will also provide electricity to Dagana. Most of the route (117 km) will be constructed in 10th FYP and the remainder (3 km) will be constructed in 11th FYP.
The on-grid electrification cost in 10th FYP will be 235 million Nu., and that in 11th FYP will be 3 million Nu., bringing the total to 238 million Nu. The off-grid investment will be 4.5 million Nu.
The on-grid electrification percentage in 2007 will be 25%, which is the lowest for a Dzongkhag. This will increase to 95% in 10th FYP and finally 96% in 11th FYP. The off-grid electrification percentage will be 4%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**S**		
2	Name of Dzongkhag	**Wangdue phodrang**		
3	Nos of Non-electrified Village	in 2003 (Actual):	155	
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	1,714	
		in 2007 (Forecasted):	**1,837**	
		in 2012 (Forecasted):	2,011	
		in 2017 (Forecasted):	2,190	
		in 2020 (Forecasted):	2,305	
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	65	(41.9%)
		11th FYP (2012-2017):	37	(23.9%)
		TOTAL	102	(65.8%)
6	Nos of Villages to be electrified by Off-grid		53	(34.2%)
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	937	(51.0%)
		11th FYP (2012-2017):	526	(28.6%)
		TOTAL	1,463	(79.6%)
8	Nos of Household to be electrified by Off-grid*		374	(20.4%)
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	128,685	2,860 (US$1,000)
		11th FYP (2012-2017):	77,878	1,731 (US$1,000)
		TOTAL	206,563	4,590 (US$1,000)
10	Investment for off-grid (x1,000 Nu.)		10,275	228 (US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	124,608	
		11th FYP (2012-2017):	71,367	
		TOTAL	195,975	
12	Dzongkhag Electrified Ratio	On-grid in 2007:	56.5%	
		On-grid in 2012:	78.7%	
		On-grid in 2017:	91.1%	
		Off-grid in 2017:	8.9%	
		TOTAL in 2017:	100.0%	
13	Features for the Master Plan			

By 2020, there will be 102 villages with 1,844 households connected the grid. This is equivalent to 66% of the total number of non-electrified villages and 80% of the non-electrified households. The number of off-grid households will be 461. The total route length of the planned medium voltage line is 196 km. Of this, 72% will be 33 kV lines and the remaining 28% will be 11 kV lines. For this route, 125 km will be constructed in 10th FYP and 71 km will be constructed in 11th FYP.

A combined length of 58 km of covered conductors will be required for four feeders which go through environmentally protected areas. Two of these feeders, having a length of 45 km, will be constructed in 10th FYP. The other two feeders, having a length of 13 km, will be constructed in 11th FYP. The lines pass through protected areas in total of 60 km.

As for 33 kV lines come from Lobesa 66/33/11 kV substation, only one 33 kV circuit breaker is installed for the supply to Punakha, Gasa, and Wangduephodraung. Thus, installation of separate 33 kV circuit breaker in each Dzongkhag needs to be examined in the F/S stage to enhance the reliability.

The on-grid electrification cost in 10th FYP will be 130 million Nu., and that in 11th FYP will be 78 million Nu., bringing the total to 208 million Nu. The off-grid investment will be 10 million Nu.

The on-grid electrification percentage in 2007 will be 57%. It will increase to 79% in 10th FYP and finally reach 91% in 11th FYP. The off-grid electrification percentage will be 9%.

*: Numbers are based on the foreasted household number in 2007.

Dzongkhag-wise Rural Electrification Master Plan

1	Dzongkhag Code	**T**			
2	Name of Dzongkhag	**Zhemgang**			
3	Nos of Non-electrified Village	in 2003 (Actual):	92		
4	Forecasted Nos of Non-electrified Household	in 2003 (Actual):	1,627		
		in 2007 (Forecasted):	**1,757**		
		in 2012 (Forecasted):	1,945		
		in 2017 (Forecasted):	2,152		
		in 2020 (Forecasted):	2,279		
5	Nos of Villages to be electrified by On-grid	10th FYP (2007-2012):	57	(62.0%)	
		11th FYP (2012-2017):	7	(7.6%)	
		TOTAL	64	(69.6%)	
6	Nos of Villages to be electrified by Off-grid		28	(30.4%)	
7	Nos of Household to be electrified by On-gird *	10th FYP (2007-2012):	1,336	(76.0%)	
		11th FYP (2012-2017):	156	(8.9%)	
		TOTAL	1,492	(84.9%)	
8	Nos of Household to be electrified by Off-grid*		265	(15.1%)	
9	Investment for On-grid (x1,000 Nu.)	10th FYP (2007-2012):	188,487	4,189	(US$1,000)
		11th FYP (2012-2017):	19,112	425	(US$1,000)
		TOTAL	207,599	4,613	(US$1,000)
10	Investment for off-grid (x1,000 Nu.)		7,712	171	(US$1,000)
11	Distribution Line Length (m)	10th FYP (2007-2012):	163,081		
		11th FYP (2012-2017):	13,412		
		TOTAL	176,493		
12	Dzongkhag Electrified Ratio	On-grid in 2007:	24.3%		
		On-grid in 2012:	81.9%		
		On-grid in 2017:	88.6%		
		Off-grid in 2017:	11.4%		
		TOTAL in 2017:	100.0%		
13	Features for the Master Plan				

By 2020, there will be 64 villages with the 1,933 households connected to the grid. This is equivalent to 70% of the total number of non-electrified villages and 85% of the non-electrified households. The number of off-grid households will be 346.
The total route length of the planned 33 kV medium voltage line is 176 km. Two (2) feeders pass through environmentally protected areas. This will required covered conductors to be applied over a total length of 39 km. Both of these feeders are to be constructed in 10th FYP.
The on-grid electrification cost in 10th FYP will be 188 million Nu., and that in 11th FYP will be 19 million Nu., bringing the total to 208 million Nu. The off-grid investment will be 8 million Nu.
The on-grid electrification percentage in 2007 will be 24%, which is second lowest for a Dzongkhag. It will increase to 82% in 10th FYP and 89% in 11th FYP. The off-grid electrification percentage will be 11%.

*: Numbers are based on the foreasted household number in 2007.

THE INTEGRATED MASTER PLAN STUDY
FOR DZONGKHAG-WISE ELECTRIFICATION
IN BHUTAN

FINAL REPORT
EXECUTIVE SUMMARY

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List of Terms

Abbreviations	English
	Bhutan Agencies
BBSC	Bhutan Broadcasting Service Corporation
BEA	Bhutan Electricity Authority
BHU	Basic Health Unit
BPC	Bhutan Power Corporation
BTL	Bhutan Telecom Ltd.
CHPCL	Chukha Hydro Power Corporation Ltd. (former: Chukha Hydro Power Corporation: CHPC)
DFO	District Forestry Office
DOA	Department of Agriculture
DOE	Department of Energy (former: Department of Power)
DOF	Department of Forest (former: Department of Forestry Services)
DOP	former: Department of Power (now: Department of Energy)
DoSLR	Department of Survey and Land Records
DOR	Department of Roads
DYT	Dzongkhag Yargay Tshogdu / Dzongkhag Development Committee
GYT	Gewog Yargay Tshogdu / Gewog Development Committee
HSD	Hydromet Services Division
MTI	Ministry of Trade and Industry
MHA	former: Ministry of Home Affairs (now: Ministry of Home and Cultural Affairs)
MoWHS	Ministry of Works and Human Settlement
MOA	Ministry of Agriculture
MOF	Ministry of Finance
NEC	National Environment Commission
NECS	National Environment Commission Secretariat
RCSC	Royal Civil Service Commission
RED	Renewable Energy Division
RGoB	Royal Government of Bhutan
RNR-RC	Renewable Natural Resources Research Centre
	Foreign organizations
ADB	Asian Development Bank
ADF	Asian Development Fund
ANSI	American National Standards Institute
DANIDA	Danish Development Assistance (under the Royal Danish Ministry of Foreign Affairs)
e7	An international NGO consisted of major 9 electric power companies from the seven G7 member countries
EOJ	Embassy of Japan
GEF	Global Environment Facility
Helvetas	NGO based in Switzerland
IDA	International Development Association
IEC	International Electrotechnical Commission
IMF	International Monetary Fund
IUCN	International Union for Conservation of Nature and Natural Resources
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency (Japan)
NORAD	Norwegian Agency for Development Cooperation

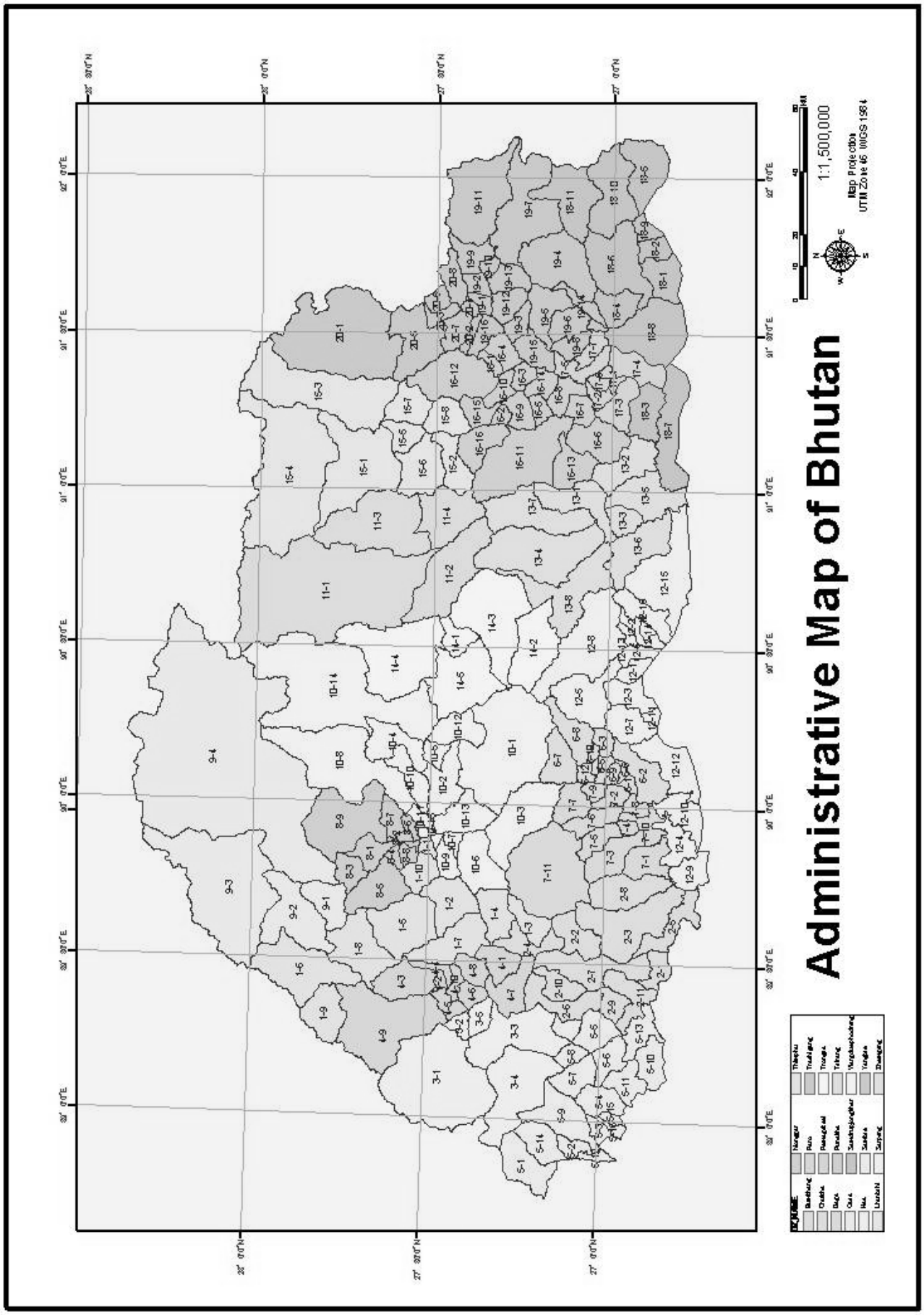
List of Terms

Abbreviations	English
PTC	Power Trading Corporation of India Ltd.
SNV	Stichting Nederlandse Vrijwilligers; NPO established in Netherlands
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
WB	World Bank
WWF	World Wildlife Fund
	Unit/Technical Terms
AAAC	All-Aluminum Alloy Conductor
AAC	All-Aluminum Conductor
ABC	Aerial Bundle Cable
ACSR	Aluminum Conductor Steel Reinforced
ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer
AVR	Automatic Voltage Regulator
BS	British Standards
B-C, B/C	B: Benefit, C: Cost
CFL	Compact Fluorescent Lamp
Ch	Chetrum
EIRR, FIRR	Economic/Financial Internal Rate of Return
EL.( ) m	Meters above Sea level
FY	Fiscal Year
GIS	Geographic Information System
GDP	Gross Domestic Product
GHG	Green House Gas
GWh	Giga Watt Hour (one billion watt hour)
HV	High Voltage
IRR	Internal Rates of Return
kW	kilo Watt
LED	Light Emitting Diode
LV	Low Voltage
MV	Middle Voltage
MW	Mega Watt (one million watt)
Nu.	Ngultrum; Bhutanese currency; 1 Nu. ≈ ¥2.6 US$1=45 Nu., if not specified
OPGW	Optical-Fiber Composite Overhead Ground Wire
Paise	Paisa (singular); Indian currency; Rs 1 = 100 paisa
PLC	Power Line Carrier
PV	Photovoltaic
SHS	Solar Home System
SHWS	Solar Hot Water System
SWER	Single Wire Earth Return
USc	US Cent; $1 = 100 c
US$	US Dollar
	Others
CDM	Clean Development Mechanism
Chimi	Member of Congress
Dungkhag	Sub-district
Dungkhag Administration	Sub-district administration
Dungpa	Sub-district administrator
Dzongkhag	District
Dzongda	Governor of the district

List of Terms

Abbreviations	English
Dzongkhag Administration	District administration
Dzongrab	Vice Governor of the district
EIA	Environment Impact Assessment
FYP	Five Year Plan
F/S	Feasibility Study
Gewog	Block
GNH	Gross National Happiness
Gup or Mandal	Executive Officer of Gewog
HEPP	Hydroelectric Power Project
ICB	International Competitive Bidding
IEE	Initial Environmental Examination
LCB	Local Competitive Bidding
L/A	Loan Agreement
Mangmi	Elected Representative of Gewog
MOU	Memorandum of Understanding
M/M	Minutes of Meeting
M/P	Master Plan
NGOs	Non Governmental Organizations
ODA	Official Development Assistance
O&M	Operation and Maintenance
PA	Protected Area
PSMP	Power System Master Plan
RE	Rural Electrification
REC	Rural Electrification Center
RESCO	Rural Electrification Service company
RE-1	Rural Electrification Programme Phase I
RE-2	Rural Electrification Programme Phase II
RE-3	Rural Electrification Programme Phase III
SEA	Strategic Environmental Assessment
S/W	Scope of Works
TOR	Terms of Reference
T/A	Technical Assistance
Tshogpa	Member of the village council
VEC	Village Electrification Committee

Prepared by JICA Study Team


Administrative Map of Bhutan
1:1,500,000
Map Projection
UTM Zone 46 WGS 1984

Standard Spelling of Administrative Units (Dzongkhag & Gewog)

Number of Dzongkhags: 20
Number of Gewogs: 201

1 Thimphu Dzongkhag
- 1-1 Bapisa
- 1-2 Chang
- 1-3 Dagala
- 1-4 Genye
- 1-5 Kawang
- 1-6 Lingzhi
- 1-7 Mewang
- 1-8 Naro
- 1-9 Soe
- 1-10 Toepisa

2 Chukha Dzongkhag
- 2-1 Bhalujhora
- 2-2 Bjachho
- 2-3 Bongo
- 2-4 Chapchha
- 2-5 Dala
- 2-6 Dungna
- 2-7 Geling
- 2-8 Getana
- 2-9 Logchina
- 2-10 Metap
- 2-11 Phuentsholing

3 Haa Dzongkhag
- 3-1 Bji
- 3-2 Katsho
- 3-3 Sama
- 3-4 Sangbay
- 3-5 Uesu

4 Paro Dzongkhag
- 4-1 Doga
- 4-2 Dopshari
- 4-3 Doteng
- 4-4 Hungrel
- 4-5 Lamgong
- 4-6 Lungnyi
- 4-7 Naja
- 4-8 Shapa
- 4-9 Tsento
- 4-10 Wangchang

5 Samtse Dzongkhag
- 5-1 Bara
- 5-2 Biru
- 5-3 Chargharay
- 5-4 Chengmari
- 5-5 Denchhukha
- 5-6 Dorokha
- 5-7 Dungtoe
- 5-8 Mayona
- 5-9 Namgyeltchholing
- 5-10 Pagli
- 5-11 Samtse
- 5-12 Sipsu
- 5-13 Tading
- 5-14 Tendu
- 5-15 Ugyentse
- 5-16 Yoeseltse

6 Tsirang Dzongkhag
- 6-1 Barshong
- 6-2 Beteni
- 6-3 Dunglegang
- 6-4 Gosaling
- 6-5 Kikhorthang
- 6-6 Mendrelgang
- 6-7 Patala
- 6-8 Phuentenchhu
- 6-9 Rangthang Ung
- 6-10 Semjong
- 6-11 Tshokhorlong
- 6-12 Tsirangtoe

7 Dagana Dzongkhag
- 7-1 Dorona
- 7-2 Drujegang
- 7-3 Gesarling
- 7-4 Goshi
- 7-5 Kana
- 7-6 Khebisa
- 7-7 Lajab
- 7-8 Trashiding
- 7-9 Tsangkha
- 7-10 Tsendagang
- 7-11 Tseza

8 Punakha Dzongkhag
- 8-1 Chhubu
- 8-2 Dzoma
- 8-3 Goenshari
- 8-4 Guma
- 8-5 Kabjisa
- 8-6 Lingmukha
- 8-7 Shenga- Bjime
- 8-8 Talo
- 8-9 Toewang

9 Gasa Dzongkhag
- 9-1 Goenkhame
- 9-2 Goenkhatoe
- 9-3 Laya
- 9-4 Lunana

10 Wangduephodrang Dzongkhag
- 10-1 Athang
- 10-2 Bjena
- 10-3 Daga
- 10-4 Dangchhu
- 10-5 Gangte
- 10-6 Gasetsho Gom
- 10-7 Gasetsho Wom
- 10-8 Kazhi
- 10-9 Nahi
- 10-10 Nyisho
- 10-11 Phangyuel
- 10-12 Phobji
- 10-13 Ruepisa
- 10-14 Sephu
- 10-15 Thedtsho

11 Bumthang Dzongkhag
- 11-1 Chhoekhor
- 11-2 Chimume
- 11-3 Tang
- 11-4 Ura

12 Sarpang Dzongkhag
- 12-1 Bhur
- 12-2 Chhuzagang
- 12-3 Dekiling
- 12-4 Deorali
- 12-5 Doban
- 12-6 Gelephu
- 12-7 Hiley
- 12-8 Jigmechhoeling
- 12-9 Lhamoi Zinkha
- 12-10 Nichula
- 12-11 Sarpang
- 12-12 Senge
- 12-13 Serzhong
- 12-14 Taklai
- 12-15 Umling

13 Zhemgang Dzongkhag
- 13-1 Bardo
- 13-2 Bjoka
- 13-3 Goshing.
- 13-4 Nangkhor
- 13-5 Ngangla
- 13-6 Phangkhar
- 13-7 Shingkhar
- 13-8 Trong

14 Trongsa Dzongkhag
- 14-1 Dragteng
- 14-2 Korphu
- 14-3 Langthil
- 14-4 Nubi
- 14-5 Tangsibji

15 Lhuntse Dzongkhag
- 15-1 Gangzur
- 15-2 Jaray
- 15-3 Khoma
- 15-4 Kurtoe
- 15-5 Menbi
- 15-6 Metsho
- 15-7 Minjay
- 15-8 Tsenkhar

16 Mongar Dzongkhag
- 16-1 Balam
- 16-2 Chaskhar
- 16-3 Chhali
- 16-4 Drametse
- 16-5 Drepung
- 16-6 Gongdue
- 16-7 Jurme
- 16-8 Kengkhar
- 16-9 Mongar
- 16-10 Ngatshang
- 16-11 Saleng
- 16-12 Shermung
- 16-13 Silambi
- 16-14 Thangrong
- 16-15 Tsakaling
- 16-16 Tsamang

17 Pemagatshel Dzongkhag
- 17-1 Borang
- 17-2 Chhimung
- 17-3 Dungme
- 17-4 Khar
- 17-5 Shume
- 17-6 Yurung
- 17-7 Zobel

18 Samdrup Jongkhar Dzongkhag
- 18-1 Dechhenling
- 18-2 Gomdar
- 18-3 Hastinapur
- 18-4 Lauri
- 18-5 Martshala
- 18-6 Norbugang
- 18-7 Orong
- 18-8 Pemathang
- 18-9 Phuentshothang
- 18-10 Samrang
- 18-11 Serthig

19 Trashigang Dzongkhag
- 19-1 Bartsham
- 19-2 Bidung
- 19-3 Kanglung
- 19-4 Kangpara
- 19-5 Khaling
- 19-6 Lumang
- 19-7 Mera
- 19-8 Nanong
- 19-9 Phongme
- 19-10 Radi
- 19-11 Sakteng.
- 19-12 Samkhar
- 19-13 Shongphu
- 19-14 Thrimshing
- 19-15 Udzorong
- 19-16 Yangnyer

20 Yangtse Dzongkhag
- 20-1 Bumdeling
- 20-2 Jamkhar
- 20-3 Khamdang
- 20-4 Ramjar
- 20-5 Tashi Yangtse
- 20-6 Toetsho
- 20-7 Tomzhangtshen
- 20-8 Yalang

Source: Ministry of Home and Cultural Affairs, Central Statistics Office, Survey of Bhutan, Department of Energy

THE INTEGRATED MASTER PLAN STUDY
FOR DZONGKHAG-WISE ELECTRIFICATION
IN BHUTAN

FINAL REPORT
EXECUTIVE SUMMARY

MAIN BODY

PART-A PRESENT STATE AND PLANING CONDITION

1. INTRODUCTION

(1) Background

At present, electricity in Bhutan is supplied to less than 50% of the whole population. The Integrated Master Plan Study for Dzongkhag (District)-wise Electrification in the Kingdom of Bhutan" (hereinafter referred to as the "master plan"), is based on a long-term and ambitious target of 100% rural electrification by the year 2020. This target is considered to be an important policy goal. In 1999, 100% rural electrification, along with poverty reduction, industrial promotion, etc, was set by the Royal Government of Bhutan (hereinafter referred to as "RGoB") as a definite numerical target in their long-term vision for Bhutan up to the year 2020 ("A vision for Peace, Prosperity and Happiness"). The policy goal can only be achieved through the achievement of rural electrification.

Before the target was set, rural electrification in Bhutan was performed by coordinating the development of electric power supply and transmission lines, taking advantage of ADB (Asian Development Bank) loans, Indian and other donors' assistance, and government activities.

In August 2001, a request for assistance was officially submitted to the Government of Japan through the official channels of RGoB. Accordingly, in October 2002 the Japan International Cooperation Agency (hereinafter referred to as "JICA"), which is an official Japanese Government agency responsible for the implementation of technical cooperation programme, sent a study team to Bhutan for project formulation. In June 2003, JICA sent a preliminary study team, to Bhutan and the study teams held discussions with RGoB on the Scope of Work for the Study. As a result, the master plan study has proceeded.

(2) Purpose of the Study

The main objectives of the master plan are to: (i) formulate a village-level rural electrification master plan which covers all of the 20 Dzongkhags of Bhutan with a combined system of on-grid and off-grid power supplies, (ii) strengthen the capacity of Bhutanese counterparts for updating of the master plan and implementation for the achievement of the goal of the electrification program up to the year 2020.

The main subjects of the master plan are as follows:

1) Database preparation for villages that will remain non-electrified after completion of the 9th five year plan (2002-2007). This work includes the preparation of maps in a geographic information system (GIS);
2) Presentation of methods for rural electrification by on-grid and off-grid electrification in the non-electrified areas. (For distribution line extension: Basic policy, standardization of planning methodology, specification of equipment adopted, and techniques for equipment specification. For off-grid systems: Application method of systems and technology, and operation and maintenance);

3) Based on (1) and (2) above, formulation of an optimal Dzongkhag-wise rural electrification plan in the non-electrified villages. (For on-grid systems, determine the number of target consumers, extension length of distribution lines, requirement for new construction and reinforcement of substations, system planning with the drawings for the 11 kV and 33 kV distribution line systems, and cost estimation. For off-grid systems, selection of power sources and their capacities, areas of supply, target numbers of consumers, cost estimation, and so forth.

4) Conduct a social study and economic evaluation, and prepare policy recommendations for the efficient implementation of the projects.

5) Technology transfer (capacity building) to Bhutanese counter parts in relevant organizations .

(3) Study Team

The members of the Study Team are as follows.

Table-1 Members of the Study Team

No.	Charge	Name
1	Team Leader / Power Planning	FUKUCHI Tomoyasu
2	Distribution System and Design Standard Planning	SHIRAKI Keiji
3	Power Distribution Facilities Planning	ARITA Toshiyuki
4	Socio Economic Study	DOBETA Kazuhiko
5	GIS / Database	USUDA Kyoko
6	Power Transmission Planning	OHARA Kazunori
7	Power Demand and Supply Planning (National Level)	NAKAJIMA Ko
8	Financial and Economic Analysis	NISHIMAKI Hiroshi
9	Small Hydro Power Power Demand and Supply Planning (Village Level)	HIRATA Kiyoshi
10	Solar Power and Renewable Energies Planning	Deepak BISTA
11	Environmental Impact Analysis	KAMISHITA Takahiro
12	Information and Telecommunication Planning	OGAWA Ryosuke
13	Coordinator (1) / Biomass Planning	NAKAGAWA Yuka
14	Coordinator (2)	YAMAMURA Kensuke

2. OVERVIEW OF THE KINGDOM OF BHUTAN

(1) Land

Bhutan is a small country located in the eastern Himalayas with a total area of 38,394 square kilometer and is surrounded by steep mountains and dense forest. The country is bordered by Tibet (China) in the north and northeast, Sikkim (India) in the west, West Bengal (India) in the southwest, Assam (India) in the south and Arunachal Pradesh (India) in the east. The total population of the country is estimated to be about 750,000[1].

[1] Statistical Yearbook 2003, NSB, RGoB

(2) Ethnic Composition

The Bhutanese are roughly classified into the following three main ethnic groups: i) The *Sharchop* who live in the eastern part of the country and are recognized as the original inhabitants of the country. They are called Eastern Bhutanese in the broad sense. Eastern Bhutan is situated in the area that includes Pele La and eastward. ii) The *Ngalop* are descendants of Tibetan immigrants who came to Bhutan in the 9th century and settled in the western part of the country. iii) The *Lhotshampa* are originally from Nepal, and settled in the southern part of the country in the 19th century. In addition to these three main groups, there are several smaller groups with their own languages. However, the total number of population of each of these minor groups is quite small.

(3) Political Organization

Bhutan is a country with a hereditary monarch. The first king, Ugyen Wangchuck, was appointed in 1907. In Bhutan, a Draft Constitution was distributed on March 2005. Government notifications, traditional customary laws, imperial orders, including oral decrees of His Majesty the King, are considered effective as laws. Under His Majesty the King, the National Assembly, Royal Advisory Council, Cabinet and High Court stand side by side.

The present Cabinet consists of 10 Cabinet Ministers, each of whom heads a ministry: (a) Ministry of Home and Cultural Affairs, (b) Ministry of Foreign Affairs, (c) Ministry of Finance, (d) Ministry of Works and Human Settlements, (e) Ministry of Agriculture, (f) Ministry of Education, (g) Ministry of Health, (h) Ministry of Trade and Industry, (i) Ministry of Information and Communication and (j) Ministry of Labor and Human Resources.

The Prime Minister is elected from among the Cabinet Ministers in rotation for a tenure of up to 1 year. The National Assembly is a one-chamber system, and consists of 151 members composed of 106 representatives elected from the people in the nation, 10 representatives selected from the Central Monastic Body and 35 representatives appointed by the Royal Civil Service Commission (RCSC) from senior civil servants, district administrators and other government officials.

(4) Development Policy

The present king, His Majesty the King Jigme Singye Wangchuck, advocated the Gross National Happiness (GNH) policy in 1976. The principal development policy of the country follows the idea of GNH, and its principal measures are to promote socio-economic development while taking actions to preserve and maintain the natural and cultural environment. These measures have been advocated to rectify the negative side of economic development, such as regional, income and educational disparities experienced by Bhutan since 1970's when modernization and the market economy were being implemented. The six (6) development goals expressed by the present Majesty the King are as follows:

- Self-reliance,
- Sustainability,
- Improvement of efficiency and development for the private sector,
- People's participation and decentralization,
- Human resources development and

- Regionally balanced development.

Development in Bhutan is managed in five-year plans (FYP's). The First Five Year Plan (FYP) of Bhutan commenced in 1961. Currently, 9th FYP is in operation, and this plan will finish in 2007.

(5) Local Administration Units

Local administration in Bhutan is under the jurisdiction of the Ministry of Home and Cultural Affairs and is implemented by local administration units called Dzongkhags (Districts) and Gewogs (Blocks). There are 20 Dzongkhags and each Dzongkhag administers a number of Gewogs. However, 8 of the largest Dzongkhags have some Dungkhags (Sub-Districts) that administer some of the Gewogs under their jurisdiction. At present, the are 201 Gewogs in total.

(6) Economic Outlook

GDP of Bhutan is US$500 million. Both the Bhutanese economy and the government have maintained good performance in recent years. GDP growth rates averaged 6.6% during 1997 and 2001. The inflation rate that hovered around 9% during the 1990's fell to less than 4% after the year 2000. The debt-service-ratio was a little over 6% during the year 2001/02, indicating sound fiscal management for the government. However, the debt-GDP ratio increased from 38.7% in the year 1999/2000 to 55% in the year 2001/02. As a result, the country's current balance of payments shows an increasing trend toward deficit, resulting from recent public borrowings that pushed the debt level upward.

(7) Economic Forecast

The economic forecast used in 9th FYP relies on the rapid growth of the electric power and construction sectors as the engine for growth, with an overall growth rate of 8.2% per annum. In the year 2000, the agricultural sector comprising grain production (17.4%), livestock (7.1%), and forestry (10%) contributed 34.5% of the total GDP in Bhutan, while the electric power and construction sectors had a share of 9.7% and 11.4% respectively. By the end of 2007, when 9th FYP will finish, the electric power and construction sectors are expected to increase their shares to 14.6% and 17.8% respectively, surpassing 12.7% for grain production. These buoyant development forecasts incorporate the construction and commissioning of new large hydropower stations, including the Tala power station.

(8) Nature and Environment

Bhutan is characterized by high altitudes, steep topography, and extensive forest coverage. The altitude of Bhutan varies from 160 m to over 7,000 m, and most of the territory is mountainous. As the country is rich in flora and fauna, it is admired as one of the "10 global hotspots".

The climate in Bhutan varies greatly according to the altitude of each area. It is explained generally that it has high humidity and temperature in the southern areas, a dry climate and low temperatures in the north, warm and dry in the ravines, and severe cold in the Himalayas. Precipitation in each area is different as well. It is less than 500 mm/year in the north,

moderate in the central region with over 1,000 mm/year, and more than 5,000 mm/year in the southern areas that are subject to high temperatures and high humidity.

3. THE CURRENT STATUS OF THE POWER SECTOR

(1) Policy, Laws, and Institutions

In order to fulfill its national policy of Gross National Happiness, 100% rural electrification by the year 2020 is one of the core policies in electric power sector. As of June 2004, out of 68,851 households in rural areas 24,833 households (36%) have access to electricity. Another pillar in power sector policy, but often in conflict with rural electrification programs, is the promotion of efficiency in power sector management, since hydropower is the primary industry for foreign exchange earnings. In conjunction with this policy, Parliament passed the Electricity Act in July 2001. According to this law, the Department of Power, the entity responsible for all the matters relating power, i.e. power sector policy, power generation, and power sales, was split into three entities. The Department of Energy (DOE) is solely responsible for policy making, the Bhutan Power Corporation (BPC) for transmission and distribution of power, and the Bhutan Electricity Authority for the regulation of the power sector.

At present the Department of Energy (DOE) of the Ministry of Trade and Industry formulates policies and oversees power generation, transmission and distribution. The DOE comprises four sections: i) Planning and Coordination Division, ii) Renewable Energy Division, iii) Hydomet Service Division, and iv) Bhutan Electricity Authority. The Bhutan Electricity Authority is now fully responsible for overseeing and regulating power generation and supply in the future. Bhutan Power Corporation (BPC) solely manages the transmit

ssion and distribution of power.

(2) Power Tariff

BPC's tariff table for household consumers is shown in **Table-2** below.

Table-2 Tariff Table for Household

Range	Tariff (Nu./kWh)
1-80 kWh	0.6
81-200 kWh	0.95
Above 201 kWh	1.2

Source: BPC

According to BPC, the average tariff was 0.9 Nu./kWh due to progressive pricing. For business users, a new access charge was introduced in the name of a Demand Charge which charges 54 Nu./kW (fixed). Volume charges are 0.95 Nu./kWh for medium voltage users, and 1.2 Nu./kWh for high voltage users.

For the consumer of power, the cost of using electricity arises not only from the monthly tariff, but also from the initial connection costs. The average connection cost in Bhutan is estimated to be 3,145 Nu. per household and this mainly covers the cost for equipment and materials required to make the power connection. The connection cost is equivalent to one

month's income for low income families, thus this cost could inhibit connection to electricity in such cases.

(3) Balance of Electricity Supply and Demand

Total installed capacity of generation was 445 MW excluding PV/Solar facilities. The system peak power demand of 105 MW was recorded in the year 2002. Hydropower sources share 97% of the total installed generation capacity. The total generated energy in 2002 was 2,200 GWh. In contrast, the total energy requirement for the whole country in 2002, including the system energy losses, was 664 GWh. Thus, the supply capacity for the whole country has sufficient surplus for both demands of peak power and energy.

Number of consumers is 47,878 as of April 2004. The average annual growth rate of consumers' numbers in the past 6 years was 12%.

(4) Financial Status of the Power Sector

The power sector in Bhutan is now divided into two divisions: i) power generation part, and ii) transmission and distribution. Three major power generation companies independently operate power stations. BPC is solely responsible for the transmission and distribution. The financial statements of BPC after its incorporation have not been released yet.

For power generation, comparing Chukha, Kurichhu, and Basochhu hydropower stations shows that it is Chukha, operated in the Bhutan's west power system, that most significantly contributes to the state income. The energy generation in Kurichhu was below the target in 2020, and it provided no contribution to the state income. Tala hydropower (1,020 MW) is a mega-project that is scheduled to be commissioned in 2006 and its annual output is planned to be 3,962 GWh. It is expected that the state income will be doubled by this project.

(5) Agreement for Power Trade between Bhutan and India

An agreement for exporting to India the surplus energy from the Chukha hydropower station (336 MW) has been concluded between DOE of Bhutan and Power Trading Corporation of India Ltd. (PTC). The effective period of the Agreement is 14.5 years from 1st October 2002. However, the unit price for export is to be revised every three or four years.

(6) Policy and Institutions Related to the Renewable Energy Systems

The Renewable Energy Division (DOE-RED) was created under the Department of Energy (DOE) in July 2002. The policy and institution regarding renewable energy conducted in RED have not been formulated yet (as at June 2004). However, as DOE-RED is a government promotion channel for renewable energy within the country, it is mandated to develop and promote all modern forms of renewable energy resources/technologies. This includes manpower development, energy conservation and efficiency improvement measures. Therefore, the current focus of DOE-RED is mainly on their solar energy programme, biomass programme, and energy conservation and efficiency improvement programme. DOE-RED is also working on development of an integrated energy master plan, and institutional capacity development.

As a future activity of RED, it is required to develop relevant renewable energy policies and legal frameworks for electrification with renewable energies.

4. EXISTING POWER FACILITIES

(1) Power System

As of June 2004, the power system of Bhutan is individually operated as a 132 kV transmission system in the eastern-central region and a 220 kV transmission system in the western region. Domestic interconnection of the two systems has not been done yet. However , transferring power flows between both systems is possible through an interconnecting line between Bhutan and the northeast part of India.

(2) Generating Facilities

Approximately 97% of the generating capacity in Bhutan is hydropower. All hydropower stations are run-of-river types, and at present all major hydropower stations are operating without serious issues. Both the Tala power station, which is under construction and targeted to be completed in 2006 with a total installed capacity of 1,020 MW, and the Basochhu-II power station, which was completed in 2004 and has an installed capacity of 40 MW, are also designed as run-of-river type stations. The generating capacity in periods of low water-flows should be examined in the future to meet increasing power and energy demands. This is because the highest demand of the country occurs in the small discharge season. In any case, surplus energy generated in the country is exported to India.

(3) Transmission Line Facilities

At present, the highest transmission voltage operated in Bhutan is 220 kV. The 220 kV lines are operated between the Chukha hydro power station and Simtokha substation near Thimphu in the western system, as well as the export-use line from the Chukha hydro power to the Birpara substation in India. The voltages of transmission lines operated in the western system are 220 kV and 66 kV, while that in the central and eastern system is 132 kV. The total length of 220 kV transmission lines is 308 km for 6 sections in the western region. For the 132 kV lines, 354.2 km is used for 9 sections in the eastern region. The 66 kV lines run over 246.1 km for 14 sections in the western region. In addition, a new 400 kV transmission line is under construction for energy export to India from the Tala hydropower station, and is to be commissioned in 2005.

Bhutan transmission lines utilize facilities having a high insulation level since the generally high altitude of the country reduces the insulation effectiveness of facilities. The conductors used for all transmission lines are standard Aluminum Conductor Steel Reinforced (ACSR). It is peculiar that conductors adopt a unique size according to voltages. In British standards, Zebra conductors (400 mm^2) are used for 220 kV lines, Panther conductors (200 mm^2) are used for 132 kV lines, and Dog conductors (100 mm^2) are used for 66 kV lines.

(4) Substation Facilities

As of July 2004, there were 9 substations with a total installed capacity of 210 MVA in the eastern-central system, and 15 substations with a total installed capacity of 812.5 MVA in the western system. All existing HV substations, except those annexed to power stations, have conventional layout and outdoor type. Operation of transmission lines and substations is

controlled through PLC[2] communications by the Kilikhar 132 kV substation in the eastern system, Simtokha 220 kV substation for the northern half, the western power system, and Singhegaon 220 kV substation for the southern half of the western power system.

A national load dispatching center (NLDC) utilizing an OPGW communications system is planned by DOE for operation and management of the power system in the near future.

(5) Distribution Facilities

Distribution Facilities in Bhutan are composed of 6.6-33 kV medium voltage (MV) lines, 400 V low voltage (LV) lines and distribution substations for 33 kV or below.

The total length of medium voltage lines is approximately 1,500 km, with about 16% of them located in Thimphu and about 18% located in Trashigang. In Thimphu, many of 11 kV lines are installed under the ground. The length of the underground lines is about 26 km and about 23% of lines

The total length of low voltage lines is also approximately 1,500 km.

As for the distribution substations, about 82% of the 794 substations are 11/0.4 kV substations.

(6) Off-grid Facilities

At the moment, the number of households electrified by off-grid systems consists of 2,336 households which use solar and 1,721 households which are supplied from small hydropower with mini-grid systems. The combination of small hydropower generators along with diesel is included in the numbers. In contrast, the number of households depending on diesel only is 129.

(7) Micro Hydro Power

As of June, 2004, 15 small hydropower plants were in operation. Of these, 13 power plants were built with Japanese Grant Assistance. Some of these power plants have already been connected to the grid.

(8) PV Power Generation Systems

Though 239 kWp of PV power generation system have been installed within the country, most of these systems were installed under development programs of foreign donor agencies. There are only a few PV projects that have been financed by RGoB. Moreover, there are local distributors developing the commercial market for PV power generation systems within the country.

At present there is no example of the electrification of a non-electrified village with PV, wind, biomass or other system utilizing renewable energies. However, there are several examples of installations of solar home systems (SHS) in public facilities, monasteries, temples, schools, health clinics, and individual households that were implemented by DOE-RED under assistance programs of foreign donors.

[2] Power Line Carrier

(9) Other Power Generating Systems

In Bhutan, Kalikhola and Panbang are the two places where diesel generators operate as off-grid systems and power distribution is done in the same way as the grid.

Neither wind power generating facilities nor biomass energy facilities have been recognized for implementation yet in Bhutan. However, some experimental plants have been introduced.

5. DEVELOPMENT PROGRAM FOR THE POWER SECTOR

(1) Power System Master Plan (PSMP)

The Power System Master Plan was studied by Norconsult International under the Norwegian NORAD fund from 2001 to 2004. The final report was submitted in April 2004. The following main themes were studied, but studies for the distribution network were outside of the scope of work:

- Large scale hydro-power projects for the ensuing term (examination of candidate sites, evaluation of those sites and ranking of candidate projects for development)
- Planning of high voltage (HV) transmission systems relating to the candidate hydro power projects, and
- Examination and recommendations to supply power to off-grid areas

The final report of PSMP details the review results of the previous PSMP on the new large scale generation development projects studied by the same consultant in 1993. The main purpose of the development is energy export to India, and also energy supply for domestic needs.

A total of 20 sites were initially selected for development from 78 candidate sites. This was done through a 9-step screening process. The list of 20 selected candidate sites was further reduced to 11 sites after examination of preliminary designs, cost estimates, and Initial Environmental Examination (IEE). Moreover, development priority among those 11 candidate sites was ranked in order of development priority. Finally, seven (7) candidate sites, including five (5) potential sites and two (2) sites that required additional investigation, were determined as priority sites to be developed by the year 2022. It is noted that the top priority site that was selected is the Punatsangchhu-I power station, for which JICA assisted with the Feasibility Study in 2000.

The development programs studied in the PSMP included i) an outline of the facilities, ii) year of commissioning, iii) interconnection with HV transmission lines for exporting energy from the above mentioned highly ranked potential power stations to the Indian grid and for domestic supply, as well as related HV substations required for the supply of industrial power that were to be completed by the year 2022. 400 kV transmission systems were considered for exporting energy to India. Standard system security criteria were applied for designing the domestic supply systems. However, the report did not discuss a load dispatching center that comprehensively manages the domestic power system in the country. The JICA master

plan for rural electrification has been formulated based on those domestic existing and planned substations.

The PSMP only suggests options for power supply to off-grid areas. No recommendation is given for specific alternatives in the areas where it is difficult to expand the grid due to accessibility and economic problems.

(2) Distribution Line Expansion Plan (ADB/RE-1, RE-2 and RE-3)

In Bhutan, three rural electrification projects financed by ADB have been implemented:

1) ADB/RE-1, planned in the 7th FYP (1992 to 1997), was completed in June 2000 and about 3,000 households were electrified.
2) ADB/RE-2, planned in the 8th FYP (1997 to 2002), was completed in December 2003. Although at first about 6,000 households in 150 villages were planned to be electrified in the project, about 7,000 households were already been confirmed as electrified by January 2004, and now more than 10,000 households in total will eventually be electrified.
3) ADB/RE-3 is currently in the implementation stage (from 2002 to 2007) and about 8,357 households are expected to be electrified.

(3) Development Planning by Off-grid Power Supply

■ Micro Hydro Power

Up until the present, surveys and planning for small hydropower, except surveys for projects where construction has been done, were carried out by the Central Water Commission of India (1980's), Swedish technical assistance (1999), UNDP/GEF (2000)[3], as well as by Bhutan's DOE.

However, each of the proposed sites in those surveys is located in areas that are relatively accessible and/or already electrified by the grid, or that are planned to be connected to the grid in the near future.

There are only two small hydropower projects that have already been selected for implementation. One is a demonstration project in Sengor, Mongar Dzongkhag undertaken by UNDP/GEF and RGoB, and the other is a small-scale CDM project in Trongsa, which was started in 2004 by e7, an NGO organized by electricity companies from seven (7) developed countries.

■ Photovoltaic (PV) Power Generation

In 9th FYP, it is mentioned that in areas where power supply is impossible by grid extension or small hydro power and so on, PV energy will be utilized. The establishment of small PV power generation systems installed in a household, Solar Home System (SHS) and Solar Hot Water Systems (SHWS) is scheduled with this plan as a use of solar energy.

[3] The surveys conducted by Sweden and UNDP/GEF were successive, and each of the two phases was carried out with each fund.

■ Biomass Energy

The consumption of the fuel wood per capita in Bhutan is one of the largest in the world. The effective use of fire wood and charcoal is thus recommended since the reduction of fire wood consumption directly affects to the preservation of forest resources.

The Global Environment Facility (GEF) provided by UNDP under their Small Grants Program (SGP) implemented a Wood Energy Conservation Project from 1998 to 1992 in Trashigang and Tsirang Dzongkhags. A similar project is now being planned by a joint Austrian-Bhutan Energy Sector Progam, and DOE-RED is preparing the proposal for it. However, no inplementation project for biomass energy for electricity generation has been planned yet.

(4) Activities of Donors in the Power Sector

Foreign aid for the power sector in Bhutan is mainly from India and large amount of the aid budget has been spent for construction of hydropower stations. ADB has provided loans for rural electrification in three Five Year Plans. ADB/RE-3, is Stage-3 of the rural electrification projects funded by ADB, and this is the third loan provided by ADB.

Austria, Japan, Norway, UNDP, the Netherlands and Sweden are the main donors for hydropower, micro hydro and solar power systems.

(5) Roadway Development Planning

In the formulation of the electrification plan in Bhutan, it is important to consider how to provide electric power to the precipitous mountain areas which comprise much of the country. When providing electricity to areas without roads, construction and maintenance is very difficult because of constraints on the availability of applicable materials or utilities, and eventually affects the materialization of the plans. Therefore, the rural electrification master plan needs to be consistent with the existing roads and future roadway planning. Many rural villages, however, still do not have access to main roads. Because of this situation, the master plan for roadway planning was prepared targeting from 10th FYP to 13th FYP (2007-2027) with assistance of ADB. However, the budget has scarcely been secured for implementation.

Moreover, detailed information on the existing roads is not available. There is no precise or detailed information existing in GIS or on topographical maps.

When formulating the distribution expansion plan, detailed expansion routes and the timing for implementation needs to be determined by first identifying the correct location of existing roads and determining the roadway development plan. Determining the exact location of existing roads and management of road information by GIS are recognized to be important in Bhutan.

6. PRESENT STATE OF THE INFORMATION AND COMMUNICATIONS SECTOR AND THE DEVELOPMENT PLAN

(1) Information and Communications Associated with Rural Electrification

In rural electrification projects, it is generally difficult to make a profit by only providing power for lighting. It is important to produce various other benefits from electrification, in addition to simply providing electricity. To make this study more effective, the feasibility of number associated activities was examined. This allowed identification of potential benefits that can be brought to rural areas. Maximizing these benefits will help to ensure implementation of the project.

By incorporating information and communications into rural electrification, the availability of the information and telecommunications infrastructure will provide assistance to local government by allowing networking of the local and the national governmental organizations. It will also provide villagers with access to remote medical care, distance education to the villages, information transmission from rural areas, an opportunity to learn about trends in the market, transmission of information about weather and disasters, and improvement in public security.

(2) Present State of Information and Communications Networks and Development Plans

Telephone, TV, radio and the Internet are used as communication methods. Bhutan Telecom Ltd. (BTL) mainly provides services for fixed telephones, GSM mobile phones and Internet. Bhutan Broadcasting Service Corporation (BBSC) provides TV and radio broadcasting services. There are a few private providers of Internet services by VSAT[4]. Cable TV operators across the country are also private companies.

Telecommunication Network

The present communications network of Bhutan Telecom Ltd. (BTL) was developed through grant aid from Japan since 1991. The network is based on microwave systems. However, the system will soon reach full capacity because of increased demand for data transmission requirements over the network. In June 2004, BTL started to use optical fiber cables installed along 66 kV electricity transmission lines to build up the transmission network.

The number of telephone line subscribers in Bhutan was 31,896 (as of June 2005). The dissemination level of telephone lines (number of lines as a percentage of the population) was only 4.3%.

9th Five Year Plan (FYP) has set a target to provide telephone services at least 10 lines to all Gewogs, and BTL is currently implementing a project to extend the telephone network to rural areas with an aid of Denmark.

GSM[5] Mobile Phone

GSM mobile phone services were started in Bhutan in November 2003. The service area was originally only along the national highway from Thimphu to Paro and Phuentsholing. However, now Punakha, Wangduephodrang, Gelephu and Samdrup Jongkhar are also covered.

[4] Very Small Aperture Terminal
[5] Global System for Mobile Communications

The number of subscribers to the service was approximately 28,500 in July 2005, and the number is still increasing rapidly. There are complaints because of congestion in the mobile network, especially at night. BTL has started the expansion work to increase the capacity and overcome the congestion problem.

■ Internet

DRUKNET is a unit of BTL and is the main ISP[6] in Bhutan. People have been able to connect to the Internet, mainly through the telephone network, since June 1999. Services are available in almost all areas covered by the telephone network. The main users are government organizations, because most private companies and the general population do not have computers. The number of DRUKNET users was 500 when the service was started. However, it had increased to 3,335 dial-up users and there were 34 leased line users by June 2005.

Most of ministries and public corporations have LAN[7] connected with Internet by leased lines. However, some Dzongkhag administrations have only recently been connected.

There are no ADSL[8] service, which is popular in Japan. Two private companies have started ISP using VSAT.

■ TV Broadcasting

Bhutan Broadcasting Service Corporation (BBSC) started TV broadcasting in June 1999. It is the only TV station in Bhutan. Since then, only people in Thimphu had been able to get broadcast TV programs directly. However, from the year 2004, they can watch BBSC TV programs in Phuntsholing area at the same time as the programs are broadcast in Thimphu because of an OPGW[9] line between Thimphu and Phuntsholing. Meanwhile, the local cable TV operator broadcasts BBSC programs that come from BBSC on videocassettes in other areas. Because of this, programs from BBSC are broadcast one to four days later than the live broadcast time in Thimphu.

There are 34 TV operators in Bhutan, serving almost all 20 Dzongkhags, except for Gasa Dzongkhag. They broadcast not only BBSC but also Indian, Chinese, British, American and Korean channels such as DDI, CCTV, BBC, CNN, and Arirang.

Satellite has advantages for the expansion of the broadcasting network in a mountainous countries like Bhutan. Actually, there is a plan to install a broadcasting satellite with assistance of the ITU[10]. However, Bhutan does not have any satellites, which means other countries control the network in Bhutan. Because of this, BBSC has great expectations for the optical fiber network. To put these thoughts into action, BBSC has requested grant aid from the government of Japan.

[6] Internet Service Provider
[7] Local Area Network
[8] Asymmetric Digital Subscriber Line
[9] Optical-fiber Composite Overhead Ground Wire
[10] International Telecommunication Union

- Radio Broadcasting

BBSC radio broadcasts programs for 11 hours a day by FM and shortwave. The broadcasts consist of five hours in Dzongkha and two hours each in English, Shashopakha and Nepalese. People can listen to the radio programs throughout almost all of Bhutan. Therefore, BBSC is popular in Bhutan. Shortwave reception is generally not clear due to the locality or timing. Now BBSC is expanding the FM network with assistance of DANIDA of Denmark.

(3) Present State and Development Program for Communication Systems in the Power Sector

The power system in Bhutan is divided in two: i) the western system, involving Chukha and Basochhu power stations, and ii) the eastern system involving Kurichhu power station. These two systems are not interconnected at present. A PLC[11] telecommunication system connects all power stations and HV and MV substations in each system for transmitting various information relating to the system operation. The PLC system is a method of communicating utilizing the power conductors of transmission lines. VHF radios are provided for backup of the PLC system.

In order to increase the capacity of information and to improve the present inefficient system operation due to inferior tone quality of the PLC system, DOE/BPC has decided to employ optical fiber cable that has a huge transmitting capacity and superior tone quality to the power system. Their plan is to replace of the existing ground wire (GW) with OPGW, which is a galvanized steel stranded ground-wire containing optical fiber cable inside and has the same protecting function for power conductors.

BPC is replacing all existing GW lines furnished on 66 kV transmission lines in the western system with OPGW. This replacement work, except for the 66 kV Chuzom-Ha section, was completed in February 2005. Although the application of OPGW to the eastern power system is not planned at present, BPC intends to provide OPGW for all new transmission lines in both the western and eastern systems.

(4) Activities of Donors in the Information and Communications Sector

Japan, UNDP, Denmark and India are the major donor groups that relate to the information and communications sector.

(5) Present Status and Possibility for Information and Communications Networks in Local Governance

Some ministries, departments, and public corporations already have a communications network system, or have plans to connect the central government and each Dzongkhag office. However, the existing systems are generally designed as dial-up access systems because of high cost of leased lines. All Dzongkhag administrations have telephone lines and a facsimile service. The Dzongkhag administrations use computers on a daily basis. However, LAN and the Internet have only recently become available in most Dzongkhags. On the other hand, there are many Gewog centers that power distribution lines or the telephone lines have not yet reached.

[11] Power Line Carrier

At present, a JICA Local Government and Decentralization Project is under way to strengthen the system of local governance, skill development of officers, and installation of necessary equipment.

A stable power supply and expansion of the communications network can provide great benefits to infrastructures such as Gewog centers, schools, agricultural centers, medical facilities including hospitals and others. Jointly providing electricity and communications should make decentralization effective in Bhutan.

7. PRESENT STATE OF NON-ELECTRIFIED VILLAGES

(1) Overview of Village Baseline Survey for Rural Electrification

The Village Baseline Survey for Rural Electrification (hereinafter referred to as the "Survey") was conducted by local subcontractors for all non-electrified villages in whole country which are to be electrified after 9th Five Year Plan (FYP). It is these non-electrified villages that are targeted by the Study. The Survey was carried out to: i) identify the location (longitude and latitude) of the non-electrified villages, ii) determine the number of households, iii) collect data on general conditions in the non-electrified villages and sampled non-electrified households, and iv) integrate the collected data into a GIS database. Further, in order to clarify future power demands, use of electricity, and issues for operation and maintenance of power supply systems, some typical electrified villages were sampled from both on-grid and off-grid villages. The Survey was extended to these electrified villages to: i) collect data on general conditions in the sampled electrified villages and households, and ii) integrate the collected data into a GIS database.

(2) Survey Results on Non-Electrified Villages

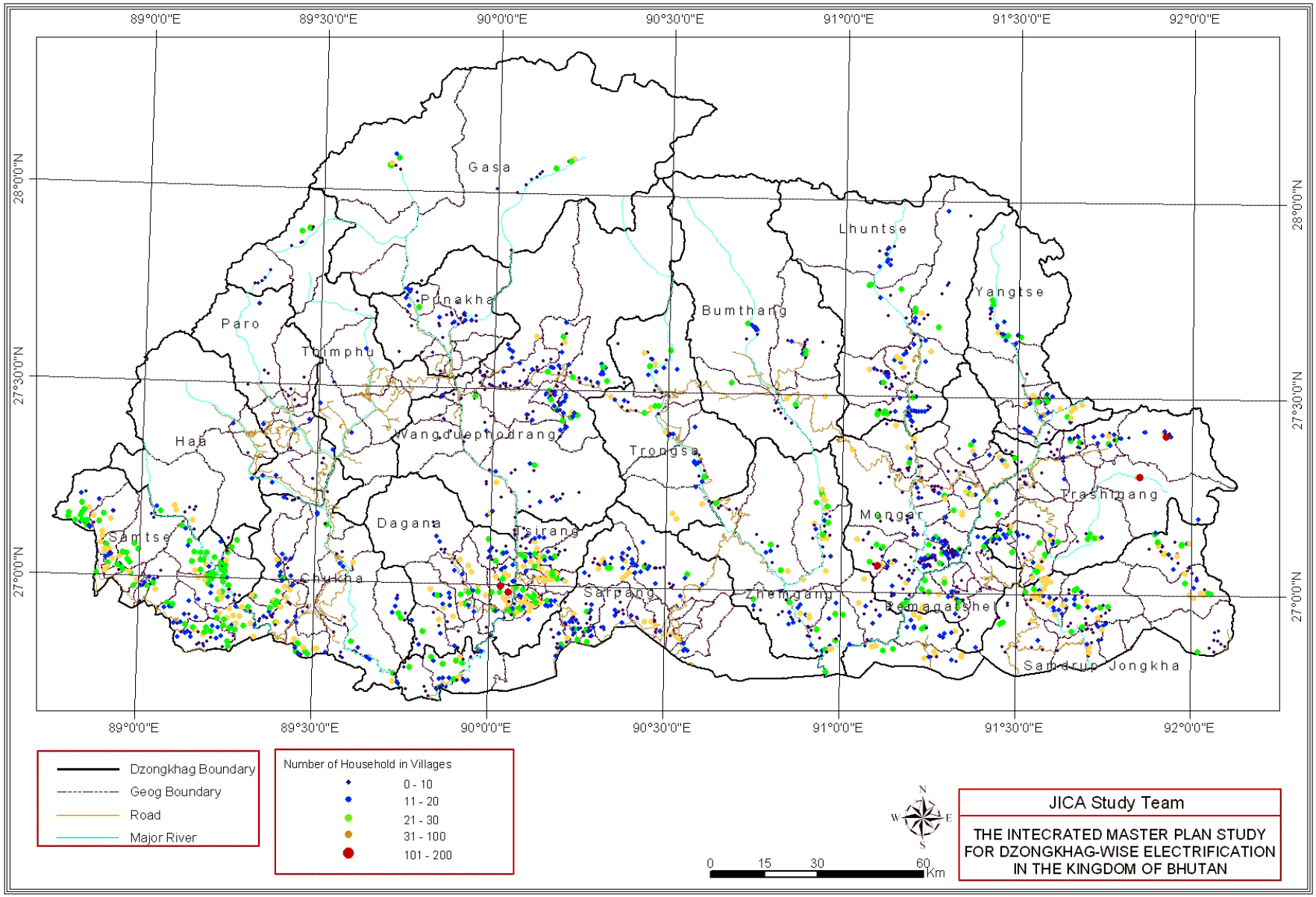
Based on the survey results, it was determined that there are 1,716 non-electrified villages to be electrified after 9th FYP. The total number of households and the total population was 29,942 and 225,658, respectively in 2004. The number of non-electrified villages and their population by district is summarized in **Table-3** below.

Table-3 Number of Villages, Households and Population of Non-Electrified Villages

Dzongkhag Name	Non-Electrified Villages		Non-Electrified Households		Non-Electrified Village Population	
	Number	%	Number	%	Number	%
Thimphu	16	(0.9)	132	(0.4)	908	(0.4)
Chukha	108	(6.3)	1,814	(6.1)	12,319	(5.5)
Haa	15	(0.9)	248	(0.8)	1,663	(0.7)
Paro	22	(1.3)	162	(0.5)	1,250	(0.6)
Samtse	181	(10.5)	4,318	(14.4)	33,757	(15.0)
Tsirang	86	(5.0)	2,186	(7.3)	18,922	(8.4)
Dagana	82	(4.8)	1,765	(5.9)	12,442	(5.5)
Punakha	35	(2.0)	263	(0.9)	2,089	(0.9)
Gasa	21	(1.2)	331	(1.1)	1,936	(0.9)
Wangduephodrang	155	(9.0)	1,714	(5.7)	12,167	(5.4)
Bhumthang	35	(2.0)	446	(1.5)	3,137	(1.4)
Sarpang	162	(9.4)	2,570	(8.6)	19,116	(8.5)
Zhemgang	92	(5.4)	1,627	(5.4)	17,637	(7.8)
Trongsa	49	(2.9)	860	(2.9)	7,214	(3.2)
Lhuntse	103	(6.0)	1,377	(4.6)	8,827	(3.9)
Mongar	183	(10.7)	2,662	(8.9)	18,617	(8.3)
Pemagatshel	33	(1.9)	650	(2.2)	4,794	(2.1)
Samdrup Jongkhar	177	(10.3)	3,573	(11.9)	25,853	(11.5)
Trashigang	105	(6.1)	2,087	(7.0)	15,175	(6.7)
Yangtse	56	(3.3)	1,157	(3.9)	7,835	(3.5)
Totals	1,716	(100.0)	29,942	(100.0)	225,658	(100.0)

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

Global Positioning Systems (GPS) were used to determine the longitude and latitude of the non-electrified villages that were surveyed. The position coordinate data were transferred to a GIS. This allowed the location of all identified non-electrified villages to be shown on a GIS-based map, as illustrated in **Figure-1** below**.**



Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

Figure-1 Location of Non-Electrified Villages to be Electrified after 9th Five Year Plan

8. PRACTICAL USE OF GIS IN PREPARING THE MASTER PLAN

(1) Introduction of GIS

A Geographic Information System (GIS) was used in the master plan to efficiently manage the spatial data on a computer. GIS is a tool that can be used for creating, editing and managing spatial data that comprises positional information (e.g. longitude and latitude) and associated attribute data (e.g. village name, number of households, population, etc.) GIS can be utilized for making digital maps and also for analyzing the data. Using GIS enables the work of creating, correcting and updating spatial data required for the Study to be done easily. Managing the database efficiently was an important task for the master plan.

(2) GIS Data Creation Situation in Bhutan

The organization which has responsibility for collecting and coordinating GIS data in Bhutan is the Department of Surveys and Land Records in the Ministry of Agriculture. In addition, many other organizations create their own GIS data, such as the Ministry of Agriculture, World Wildlife Fund (WWF), local consultants, etc. However, since each organization creates GIS data independently, the accuracy of the data is not uniform and management of the data is not coordinated. External users of the data do not have access to metadata that describe basic information about the data, such as the base data, the data accuracy, the date of data creation, and so on. Moreover, the coordinate systems are different among the various organizations and local consultants since an international standard coordinate system is not used in Bhutan.

(3) Creation of a National Contour Map

The master plan needed elevation data to calculate the 3D length of electricity distribution lines. However, as a result of investigations, it became clear that there was no existing digital data in Bhutan which were known to have a suitable accuracy and reliability. Therefore, the Study Team needed to create a GIS contour map of the whole of Bhutan using satellite images.

The satellite images were ASTER data supplied by the Earth Remote Sensing Data Analysis Center (ERSDAC) in Japan. The advantages of using ASTER data are as follows:

1) It is possible to derive topographical data (contour lines) automatically.
2) The data accuracy is unified by using the same image sensor for all of Bhutan.

The maximum elevation error is less than 15 meters (the officially quoted value), so it is possible to satisfy the accuracy requirements of the master plan

(4) The Interface with Other Programs

The Study Team also used the GIS as a tool for the database management. The master plan data which were examined in GIS had to be transferable to other computer programs that were used in preparing the master plan, such as the power flow analysis program and the economic optimization program. After the master plan data were analyzed by the other programs, the analysis results were transferred back to the GIS so that the GIS contained all relevant data. A data exchange interface was set up to allow this two-way transfer of data to be done efficiently.

9. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

(1) National Environmental Strategies

The existing national strategies and plans relating to the environment provide for sustainable development. These strategies and plans do not preclude development that incorporates adequate consideration for sustainability of the environment.

(2) Environmental Legislation

Acts and regulations relating to nature conservation are well addressed in Bhutan. It is believed that this situation is partly due to the fact that the country has a rich natural environment. On the other hand, regulations relating to public pollution have not been prepared in so much detail.

The "Forest and Nature Conservation Rules of Bhutan" are designed to preserve the nation's forests. Four (4) national parks, one (1) nature reserve, and four (4) wildlife sanctuaries have been declared as protected areas (PAs). Five of these nine PAs already have a management plan.

The Department of Forestry, Ministry of Agriculture (MOA) continues to define forest management units (FMUs) in order to promote sustainable forest management. Fourteen FMUs are in operation and seven FMU's are planned for establishment.

The "Environmental Assessment (EA) Act 2000" and the "Regulation for the Environmental Clearance of Projects and Regulation in Strategic Environmental Assessment" comprise legislation relating to environmental impact assessment in Bhutan. The regulations are based on the provisions of the EA Act 2000. Sectoral Guidelines were prepared with the assistance of the Asian Development Bank (ADB) in 1999. These guidelines were revised in 2003 to conform to the Regulation for the Environmental Clearance of Projects. The "Sectoral Guideline for Transmission Lines", originally prepared in 1999, was revised and renamed "Sectoral Guideline for Transmission and Distribution Lines" in the 2003 revision.

(3) Environmental Laws and Procedures Relating to Rural Electrification

The EA Act 2000 requires proponents to obtain an environmental clearance from the National Environmental Commission Secretariat (NECS) prior to the project implementation.

The project proponents have to submit "Environmental Information" regarding the proposed project and an application for environmental clearance to NECS.

The project proposal is officially announced after completion of an internal examination to determine if it is appropriate. Then NECS conducts project screening based on the environmental information that is submitted by the proponent for the screening process. This results in the proposal being classified into one of following three categories:

- Issuance of environmental clearance;
- Requirement of EIA for further examination of the environmental aspects; or
- Issuance of a blanket denial for the project

When an EIA is required, the proponent has to prepare the terms of reference (TOR) for the EIA. After the TOR is approved by the NECS, the proponent prepares and publishes an

Environmental Assessment Report. When the proponent completes the publication in accordance with the terms defined in the relevant regulation, the NECS issues an environmental clearance based on the report. So far, there has not been any case which an EIA has had to be completed under the EA Act 2000, except one case that the environmental assessment for transmission lines project is now being processed.

The Land Act 1979 describes the procedure for land acquisition that is required when a project site includes registered private land. The proponent of a project is required to apply in writing to MOA for approval prior to the clearance of Government Reserve Forest for governmental purposes such as road construction, irrigation channels, transmission lines for electricity, telephones etc.

(4) Environmental and Social Considerations in Relevant to Preparation of the Master Plan for Rural Electrification

None of guidelines on strategic environmental assessment tools and procedures have been published yet. Currently, Strategic Environmental Assessment (SEA) is not mandatory for development plans, etc. It has not been practical in Bhutan to approve the implementation of SEA officially. Therefore the environmental examination in the Study included SEA as a case study by basically following the regulation in Bhutan. During the environmental examination, the Study Team regarded SEA as "an environmental consideration in the master plan planning stage".

Environmental aspects and items to be considered in the environmental consideration were decided after considering not only Bhutanese legislation and JICA guidelines for environmental and social considerations, but also the environmental guidelines of international donors such as World Bank, ADB, and JBIC.

(5) Effort for Utilization of Clean Development Mechanism and Application to the Project Proposed in the Master Plan

■ CDM Efforts and Present Status

The micro hydropower project in Chendebji village in Trongsa Dzongkhag, which is being implemented by the 'e7' group, is considered to be a clean development effort at a specific project level. The 'e7' group consists of 9 companies from the developed countries that attend the G7 meetings. This project is an application of a small scale Clean Development Mechanism (CDM) supported by the "e7 Fund for Sustainable Energy Development". Both the RGoB and the Government of Japan have approved the project as a CDM application. The project has been validated by the CDM DOE (Designated Operational Entity), and was registered by the CDM Executive Board (EB) on May 23, 2005.

■ (Possibility of Application of CDM for the Rural Electrification Project in the Master Plan)

Smaller-scale CDM projects than Chendebji may be applicable if the project site is located in an area where it will be electrified by off-grid. When a CDM application is actually prepared, further study and examination would be required to obtain various base data required to introduce the project logically.

1) The targeted area would be electrified by diesel power generation and not have on-grid electrification. In the case of electrification by on-grid as a CDM project, the assumed emission of CO_2 from diesel power generation must be reduced.
2) Firewood would be consumed continuously and the consumption of firewood would increase, because of factors such as increasing population, without on-grid electrification. In the case of on-grid electrification as a CDM project, the assumed emission of CO_2 from firewood combustion in households could be reduced. (It is regarded that the reduction of CO_2 emission from increase of firewood consumption is countable in CDM in this baseline scenario. However, CO_2 emitted from the combustion of biomass, which includes firewood, cannot be counted in sustainable conditions.)

PART-B PLANNING METHODOLOGY AND ANALYSIS

10. TECHNICAL STANDARDS FOR POWER FACILITIES

(1) Present State of Technical Standards for Power Facilities

National or institutional technical standards for the power sector have not been issued yet in Bhutan. However, the following items are noted in Power Data issued by DOE::

- Allowable maximum voltage variation of transmission lines and distribution lines should be within ±5%.
- Allowable maximum frequency variation should be within ±3%.

Many of the existing power facilities were installed by the aid of India, and the Bhutan power grids are interconnected with the Indian grid. Accordingly, Bhutan refers to the technical standards issued by Central Electricity Authority (CEA) of India.

(2) Technical Standards for Distribution Facilities

There are no unified electrical standards in Bhutan. Existing facilities were constructed in accordance with the individual standards of each project. There are only small differences among standards for ADB/RE-1, RE-2, RE-3 and the DOP Standard that was drawn up in 1998 and is used for small-scale projects.

In BPC, maintenance and inspection are performed based on the "Maintenance Schedule for Distribution Systems", which is the guideline for maintenance work. The guideline shows detailed maintenance and inspection items for facilities such as the distribution transformers, the overhead and underground medium voltage distribution lines, the low voltage distribution lines and service wires, and recording forms. Although the period for each maintenance and inspection work item is also outlined in the guideline, the work should actually be performed by the instructions of a manager. Maintenance records are kept, but there is no definite safekeeping period for these records.

(3) The Problems from Previous RE Projects

■ Use of Large Capacity Transformers

In ADB/RE-3, the capacity of most designed transformers is 63 kVA. Transformer installation work depends on manpower in the mountainous areas, and this causes difficulties for the workers because the 63 kVA transformers (33 kV, 3 phase) are very heavy (700 kg). Moreover, in the districts where the density of power loads is small, it is not economical to use large transformers because the cost of the high cost of low voltage lines and the problem of low voltage lines causing considerable energy loss.

■ Decision on Standardized Span

In former rural electrification (RE) projects, the standardized span was decided based on the height of poles and the permissible clearance between a distribution line and the ground. The standardized span is useful for the flat land areas. However, the standardized span, has no significance in mountainous areas, especially when a line is installed across a valley.

■ Low Utilization Rate of Distribution Transformers

The capacity of distribution transformers installed in previous RE projects is relatively excessively high compared to the actual demand. Installing transformers with capacity greatly in excess of the required level leads not only to over-investment, but also to the increase of no-load losses that are generated independently of the load. Therefore, the economic loss resulting from installing such high capacity transformers is very large.

■ Difference of Distribution Line Length between the Plan and Actual Work

In the former RE projects, the route design of distribution lines was often decided without considering the geographical features of the sites. Therefore, there were some cases where the designed distribution line route bypassed valleys, cliff lines, etc with a straight line. In these cases, the actual construction had to go by a roundabout route to avoid these difficult geographical features and the cost greatly exceeded the budget.

■ Extension of Distribution Lines from Smaller Capacity Lines

Normally, the installed conductor capacity is decreased towards the end of a line. However, in some existing lines, there are a few sections where a thicker (higher capacity) conductor has been connected after a thinner (smaller capacity) conductor. This situation may cause an over-current in the thinner conductor.

(4) Technical Standards Requested by the Bhutan Side, and the Results of Consideration

Following request of technical standards from the Bhutan side were considered.

■ Poles

Panzer masts (fabricated steel poles) and wood poles are considered to be applied because of better workability. Limited application of panzer masts and wood poles are proposed.

■ Conductors

The possibility to apply AAC (All-Aluminum Conductor) was considered. However, ACSR is used as the standard specification because the cost benefit of using AAC is only 1-2%. Covered conductors are to be used in environmentally protected areas where an approval for tree trimming may not be easily attained.

■ Transformers

Single-phase transformers will be used for villages in this RE project where three-phase demand is not anticipated in the future.

A Single Wire Earth Return System (SWER) was also considered. However, several disadvantages were found. Mold transformers were also considered. However, the price is more than double, though the weight of the mold transformer is roughly the same as, or greater than, a regular oil immersed transformer. Therefore, there is little advantage in using mold transformers, except for special purposes in Bhutan.

■ Insulators

Porcelain insulators are currently used in Bhutan. However, since there are cases of damage to the porcelain insulator due to thrown stones, the Study Team summarized the characteristics of 3 types of insulators such as performance, workability, and economy and

studied their feasibility. Considering the advantages and disadvantages of each type of insulator, it is desirable that porcelain insulators are used as the standard specification, and that glass insulators and polymer insulators are used in mountainous areas. Glass insulators are used where extensive time is spent on investigating any problems, and the polymer insulator is employed where the priority is workability.

■ (Voltage Regulators)

It is mentioned that the adoption of a voltage regulator is one effective solution to ease the voltage drop since voltage drop often becomes a problem when long distance medium voltage lines are installed.

■ (Coupling Transformer)

In rural areas, there are some villages where demand is very low and the capacity of transformers to match the demand may be less than 10 kVA. In the case of 33 kV, it is very difficult to procure a transformer whose capacity is less than 25 kVA. The use of a coupling transformer that converts the voltage from 33 kV to 11 kV and the use of small capacity transformer for 11 kV is an effective solution.

(5) Technical and Design Standards for the Master Plan

The Study Team investigated the technical and design standards by taking the following 3 factors into consideration, then decided on suitable standards for Bhutan:

■ Safety and Reliability

Since distribution facilities such as power poles and lines are exposed to wind and rain, and will be installed next to inhabited areas, standards should be studied considering the safety and the reliability of these facilities.

■ Workability

In Bhutan, which features predominantly mountainous terrain, transportation of materials and equipment relies upon manpower. Therefore, the weight of materials and equipment affects the workability of construction, making this an important decision for the standards.

■ Economy (Life Cycle Costs)

Though initial costs tend to be given priority in cases of rural electrification because of financial problems, life cycle costs including O&M costs and energy losses are also very important for sustainable operation.

11. OFF-GRID ELECTRIFICATION PLANNING

(1) Renewable Energy Potential

■ Meteorological and Hydrological Data

In Bhutan, the Hydromet Services Division of DOE is responsible for all hydrological and meteorological observations and data management, nation wide. There are 84 meteorological stations in total throughout Bhutan, 12 agro-meteorological stations (Class A),

and 64 climatological stations (Class C), which are all managed by DOE. Manual observations are generally made twice a day (at 9:00 am and 2:00 pm) at these stations.

As for hydrological stations, there are 16 primary gauging stations installed in the main river system and 8 secondary gauging stations, in which observations of water level, discharge, and sediment/suspended load sampling have been made since 1987. Also in DOE, dry season discharge has been observed one or two times a year during the dry-season (December to April) since 1992 at 72 stations on the medium and small sized rivers (Lean Season Stations).

■ Micro Hydropower Potential

A nation-wide study to quantify the potential for small/micro-hydropower generation has not been conducted up until now. However, the observation records of the lean season discharge at 72 stations on small-scale rivers shows that the eastern region of Bhutan is generally expected to have a large potential for micro/small-hydropower due to adequate dry season discharge rates. This is especially so in the north-eastern region, such as Lhuntse、Yangtse, and for Punakha Dzongkhag in the central region. In contrast, the western region, such as Thimphu and Chukha Dzongkhags, show a low specific dry season discharge compared with other regions. However, the specific discharge is not small compared to that of other countries. Depends on catchment areas and topographic conditions, the potential for mini/micro hydropower would be preferable.

■ PV, Wind and Biomass Energy Potential

When sizing PV power generation systems, solar irradiation data becomes essential. However, these data do not exist in Bhutan at present, except for a few observation data. Therefore, satellite data from the National Aeronautics Space Administration (NASA) in U.S.A. are used for making these estimations at present. It is understood that in the southeastern part of Bhutan, which has a lot of precipitation in the rainy season, there is an average of 4.3 kWh/m^2/day. In Gasa Dzongkhag, which is in the northern part of Bhutan, and also in the western part of the country, there is a higher solar potential of more than 4.6 kWh/m^2/day on average. The country average is over 4.4 kWh/m^2/day, and it can be said that the solar potential in Bhutan is high and there is not a lot of difference from the average between each area.

As for wind power in Bhutan, considering the geographical features and inaccessible high mountains, it is assumed that there would be a high potential However, at present there is no development project using wind power generation. Calculations of wind power generation potential and development of a wind map has not been done.

Most of the land in Bhutan is covered by the forest and it can be assumed that the biomass potential is high. However, there is no biomass power generation plan being formulated at present, and little data are available for biomass power generation systems.

The climate in the southern part of Bhutan is warm, and the agricultural system of half-cropping and half-livestock farming is popular. Thus, the biomass potential of biogas using livestock dung is believed to be high.

(2) Technical Criteria Applied to Existing Off-grid Electrification

Currently, the technical criterion of each donor is applied for each project of micro hydropower and PV power generation. There are no technical criteria of wind and biomass energy power generation because there is no example, except for experiment facilities.

(3) Technical Standard and Model for the Master Plan

■ Micro Hydropower Generation

There are currently 13 micro/small hydropower generation plants that were constructed with grant aid from Japan. Most of these are still in operation without any serious problems, even though more than 10 years has passed since they were installed. In this master plan, there are no foreseen problems in following the technical criteria that were applied to the previously cited mini/micro hydropower generation plants constructed by Japanese grant aid.

Regarding the transmission voltage, 6.6 kV was adopted in the power plants installed with Japanese grant aid. However, this voltage is not common in Bhutan. Therefore, 11 kV or other standard voltage in Bhutan is desirable, considering the availability of spare parts and future connection to the national grid.

Since the design of each micro hydropower is different from others because of the site criteria, it is impossible to show a standard model for hydropower. It is expected that peak demand will increase rapidly in the near future because electricity is used for heating, even in rural area in Bhutan. If the capacity of the head tank is increased and water is stored when the load is low, the peak demand can be catered for to some extent.

■ PV Power Generation Systems

International technical standard will be applied. Solar home systems (SHS) will be applied as a model because houses are generally scattered in rural areas in Bhutan. Two kinds of model are shown, one is a small scale PV system for lighting with 45 Wp and the other is large scale PV system to supply the same quality/quantity of electricity as an on-grid power supply, with 550 Wp. LED lamps are to be applied as standard for lightning equipment in small scale PV systems.

■ Biomass Energy

Electricity generation systems that use biomass are categorized into three types: i) direct combustion of biomass by a boiler-turbine system to generate electricity, ii) biomass gasification to produce a gas for powering an engine generator, and iii) biomass fermentation to produce a fuel (methane gas) for powering an engine generator. The scale of a biomass boiler-turbine electricity generation system applies to grid supply, for which the established power source is a large hydropower generation system in Bhutan. Thus, a boiler-turbine type of generator would not be suitable for use as an off-grid power source. As for gasification, biomass collection is necessary, such as rice husks, wood chips, or saw dust. The amount of biomass that needs to be collected is on the scale of rice mill or saw mill production from an economic point of view, since it needs transportation of large amount bulky materials. It is highly possible that places that have a rice mill or a saw mill are to be electrified by grid extension. Therefore, direct biomass combustion is not suitable for use of

an off-grid power source. In contrast, biogas (methane) produced by biomass fermentation is applicable to household-scale energy consumption.

Accordingly, the proposed model for the utilization of biomass in Bhutan is that biogas is used as the energy source for cooking and that a photovoltaic (PV) system be used for lighting. Therefore, use of a biogas system for cooking would supplement the off-grid solar home (small scale PV) system used for lighting.

12. POWER DEMAND FORECAST

(1) General

Firstly, a review was made of power demand forecasts estimated in past, such as ADB/RE-1, RE-2, RE-3 and the Power System Master Plan (PSMP).

The demand forecasts for non-electrified villages that are applied to the master plan are based on the field surveys of non-electrified/electrified villages that were conducted by local consultants.

Power demand forecast in non-electrified villages is the most important in this master plan. Additionally, demand forecast in electrified villages was also done. Comparison with the PSMP and consideration of the nation-wide power demand balance was also done by applying demand forecasts for non-electrified/electrified villages.

(2) Method of Power Demand Forecast in Non-Electrified Villages

The villages for this master plan study are mostly small-scale. According to the results of the non-electrified village survey that was done by the Study Team, there are about 10 households in the majority of villages. Therefore, the power demand of rural villages in Bhutan will be mainly from the domestic sector. In villages that are somewhat larger in size, households would also be the major consumer of electricity. However, there would be additional power demands from commercial buildings/shops, schools, clinics, temples and small industries with smaller power demands.

Based on the results of the analysis of actual electric power utilization in the electrified villages, the unit power consumption per consumer of each sector (domestic, commercial, industry and public) was estimated. Applying the unit energy consumption to the number of households and considering the growth rate of consumption in each sector, the Study Team prepared a power demand forecast for the specified horizon year of 2020. The forecast was carried out in 4 phases for the years 2007, 2012, 2017 and 2020. These years correspond to the end of the 9th, 10th, 11th and 12th FYP, respectively. The forecasting period was extended to the year 2030 in accordance with the request of DOE/BPC. This extended forecast was prepared by following the same trend as for the forecast demand in 2020.

(3) Results of the Power Demand Forecast in Non-Electrified Villages

The average annual growth rate of the projected peak demand in the period of 2003 to 2020 is 2.4%. The rate of energy consumption in the same period is 3.4% at the national level.

The maximum peak demand at the national level is 58 MW, and the average monthly energy consumption is estimated to be around 9.6 GWh in 2020.

The peak load of 1.25 kW per household in 2003 is expected to increase to 1.47 kW per household in 2020. The average monthly energy consumption is expected to grow from 120 kWh per household in 2003 to 141 kWh in 2020.

(4) Results of the Power Demand Forecast in Electrified Area

At the national level, by the year 2020 the total peak load will increase to 3 times the 2003 level and the energy requirement will increase to 4 times the 2003. The average annual growth rates for the total peak load an energy requirement over the same period for the medium growth scenario are 6.7% and 8.6%, respectively. The estimated peak load will be 384 MW in 2020 and the annual energy demand will be 2072 GWh.

The industrial sector consumes about 80% of total energy requirement of the country. By 2020 the average annual growth rate of the industrial and domestic sectors will be 9% and 5%, respectively. Higher growth rates for energy consumption will result in Sarpang, Zhemgang, Mongar, and Samdrup-Jongkhar Dzongkhags where large-scale factories are planned.

(5) Demand Forecast for Whole Country

The average annual growth rate of the peak load in the period of 2003 to 2020 was estimated to be 7.4%, and that of the energy consumption is estimated to be 9.2%. The national level peak load in the year 2020 was projected to be 440 MW and energy consumption was projected to be 2,200 GWh.

The ratio of energy consumption by the non-electrified villages to the total national consumption is around the 10% mark before new industries come into operation and this will decline to around the 5% mark after new large-scale industries become operational. The power market in Bhutan is largely influenced by the industrial sector. Thus, the forecast demand should be frequently reviewed after any changes in socio-economic circumstances, changes in development plans of each sector, and other related events.

(6) Comparison of Forecast with PSMP Forecast

As the industrial demand share is at about 80% of the total national demand, it greatly influences the overall demand forecast. For example, there is a difference of 595 GWh between the projected energy demand estimated by the Study Team and that estimated by the PSMP in the industrial sector for the sample years of 2013 and 2020.

It seems that the PSPM considered only part of the demand resulting from expansion plans of existing factories. Development plans of new factories approved by DOE were apparently not evaluated by the PSMP. In contrast, the Study Team's forecast takes into account the full demand of the factory expansion plans, although some modifications were made in the Medium and Low Growth Scenarios. However, both forecasts are very similar for other sectors than industrial sector.

(7) Balance of Demand and Supply

The results of examining the demand and supply balance are as follows:

a) Annual balance for the entire country: Supply capability exceeds demand for both peak load and energy consumption.

b) Balance in dry season in the entire country: Sufficient supply is available under medium growth scenario, although a slight shortfall in energy supply is foreseen during 2 years (2010 and 2011) high growth scenario. However, this shortfall will be fully offset by commissioning the Punatsangchhu-I power station in 2012.

c) Annual and dry season balance of each power system: Sufficient supply capacity is available in the western power system. However, the following shortfalls are foreseen in the eastern power system during the period of 2007-2011.

- Under the high growth scenario: annual and dry season energy and peak load
- Under the medium growth scenario: annual peak load

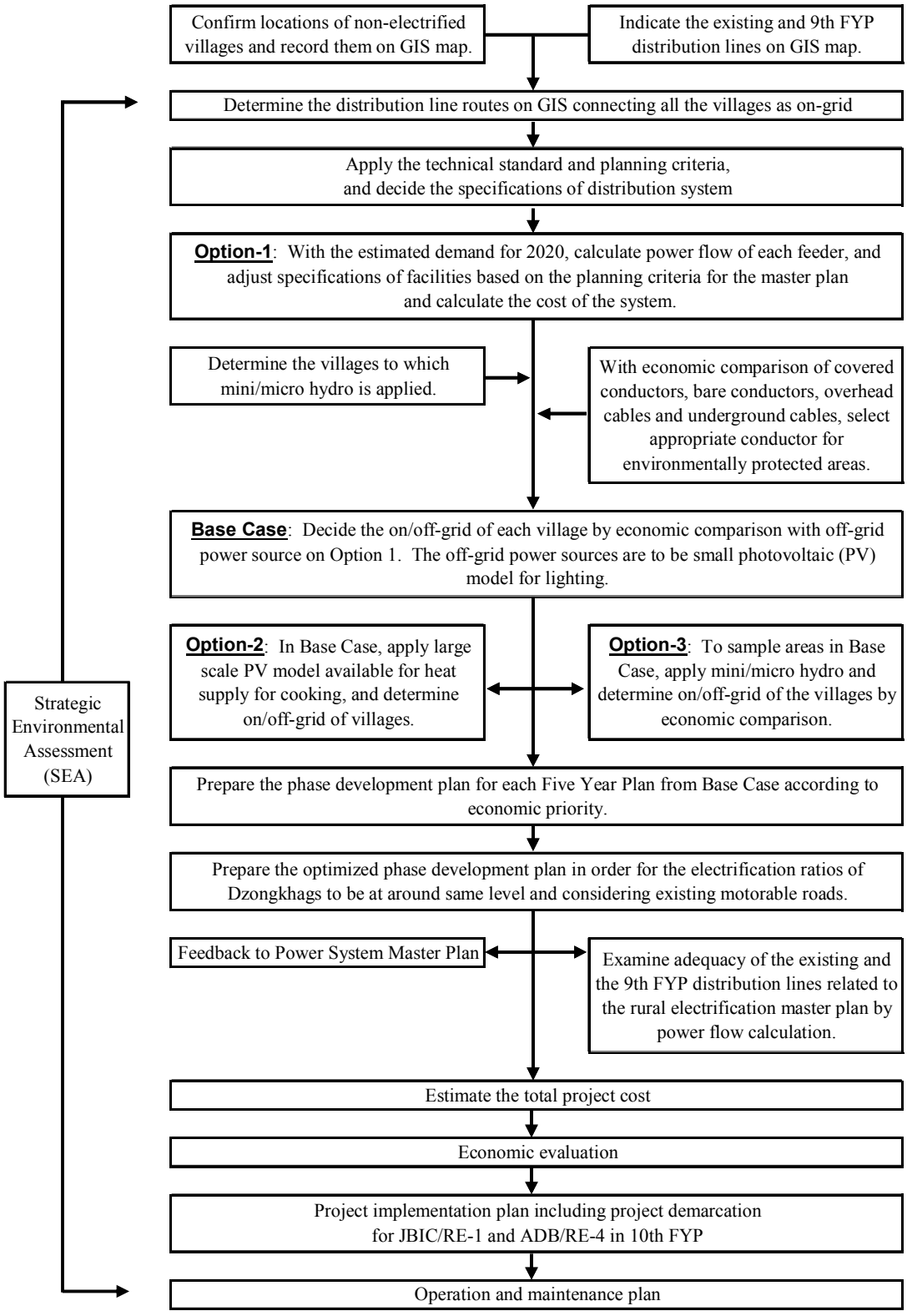
Transfer of surplus energy in the western system to the eastern system will fully resolve the shortfall in the eastern system. This transfer will be made through the Indian grid, because the 132 kV lines between Tsirang-Chowabari or Punatsangchhu-Sarpang-Chowabari-Gelephu are scheduled to be commissioned in 2012.

Demand forecast and implementation schedules of the planned industrial estates should be frequently reviewed, and necessary adjustment measures should be taken in advance.

13. PLANNING METHODOLOGY OF RURAL ELECTRIFICATION

(1) Work Flow of the Master Plan

The overall flow of the formulation of the Master Plan for rural electrification is shown in **Figure-2** below.



Prepared by JICA Study Team

Figure-2 Flow of the Formulation of the Master Plan for Rural Electrification

The location of all the non-electrified villages was recorded by GPS in the village baseline survey and positional coordinates comprising longitude (X), latitude (Y), and elevation (Z) of those villages were entered into the master plan GIS database. Similarly, all the existing distribution line routes and the routes of distribution lines to be constructed under 9th FYP were indicated and added to the GIS. The new distribution lines will be extended to the target non-electrified villages from the end points of either the existing lines, new lines that are to be constructed during 9th FYP, or substations. Firstly, the Study Team connected all the non-electrified villages by the extension of the distribution lines. This was done in order to gain an understanding of the extent and cost of the 100% on-grid electrification scenario; this case is named "Option-1". The routes of the distribution lines were selected by using the GIS map.

Potential sites for mini/micro hydropower generators were selected and map based studies were done. For environmentally protected areas, the selection of the conductor to be adopted was done by taking into account the cost and environmental impact mitigation.

The allocation of all the non-electrified villages to either on-grid or off-grid status was decided by economic comparison of on-grid and off-grid costs and benefit. On-grid costs were estimated from the result of Option-1 (see above). The particular type of conductors were selected for environmentally protected areas. The off-grid power source is a small PV model for lighting. This case was named "Base Case".

Another two option studies were conducted using Base Case. Option-2 was on/off-grid decision using a large scale PV model as the off-grid power source. This system would have enough capacity to supply electricity for cooking in addition lighting. Option-3 was prepared for selected villages where the use of mini/micro hydro power might be appropriate as the off-grid power source. (See Chapter 14.)

The Study Team prepared the phase development plan for each FYP from the Base Case. The implementation order was decided according to economic priority (See Chapter 15). Equal development of the country is a policy of the RGoB. Therefore, the Study Team optimized the phase development plan in order for the electrification ratios of Dzongkhags to be at around same level in the early phase of the FYP's. Furthermore, priority was given to the feeders that were near the existing trafficable roads. (See Chapter 16.)

The result of the optimized master plan that was formulated for rural electrification was fed back into the Power System Master Plan. The adequacy of the existing and 9th FYP was examined on the optimized phase development plan.

Finally, the total project cost was estimated, economic and financial evaluations were done, and the project implementation and operation and maintenance plans were prepared. (See Chapters 19, 20.) In addition, for the implementation plan, the Study Team proposed the project demarcation for JBIC/RE-1 and ADB/RE-3 in 10th FYP.

(2) Network Optimization Method for Determining Grid Extension

In Bhutan, it is expected that grid extension will cover the majority of the future rural electrification needs, while some remote areas will employ independent off-grid electrification systems because of prohibitive economic costs.

One of the major tasks of the rural electrification master plan is to determine how the existing distribution network could be extended. It is easy to understand the rationale for making the judgment to extend or not extend the power grid in extreme cases, for example, extending the grid to a village with hundreds of houses and that is located only few hundred meters away from an existing power line, or not extending the grid where a remote village comprising just a few houses is tens of kilometers away from an existing line. When deciding whether to extend the grid or not, the main problem lies in the middle ground, for example, where a village with 20 to 30 households is located only a few kilometers away from an existing power line.

The decision to extend the grid to a village that is located near the end of a distribution network will depend on the on/off grid determinations that are made for the preceding villages in the chain. The cost justification of the inner links will be influenced on the benefits of all the subsequent dependent links. Even if the inner link to one settlement does not justify itself independently because it has a negative net economic benefit, if the outer locations have large enough positive economic net benefits to offset the negative net benefits of the inner node, then linkage of the entire chain to the grid can be justified. Theoretically, the economic justification of an inner extension depends on the sum of the net benefits brought by all the subsequent forward linkages, which was evaluated for on/off decision.

(3) Methodology for Economic Analysis

In the economic analysis for the master plan study, the economic benefits for electrification are quantified on the basis of consumer surplus. The benefits or costs of the project in question need to be measured as differences between doing the project and not doing the project, which is the so-called “With/Without” case analysis. The derived cost and benefit flows are summed into the net present values to derive an economic internal rate of return (EIRR) on the investment.

There are three types of rural electrification methods: i) connection to the grid, ii) an independent grid, and iii) a solar home system. While a solar home system simply replaces kerosene lamps with fluorescent lamps that give a much brighter light, fully-fledge electrification gives more capacity and options for the use of electricity. A higher output capacity enables the use of a TV or radio, and also rice cookers. A typical solar home system that only provides for limited use of electrical appliances bestows a lower level of benefits than grid-based electrification.

14. ANALYSIS OF RURAL ELECTRIFICATION

(1) Overview of the Rural Electrification Master Plan

A determination was made whether a particular electricity distribution line will be extended (on-grid) or not (off-grid) by 2020, which is the target year of the master plan. The basis of the determination is an economic calculation that compares the difference of benefits and costs for grid extension and installing a 45 Wp small scale solar home system (SHS).

Out of the 1,716 villages that were analyzed, it was found that grid extension was more economically beneficial than solar for 1,267 villages (74% of non-electrified villages). This

is defined as "Base Case". **Figure-3** shows a map of the nation-wide power distribution lines in Bhutan and also the on-grid and off-grid villages.

The total route length of medium voltage distribution lines was determined to be approximately 2,322 km. The total on-grid electrification cost is estimated to be US$71.4 million and that for the off-grid electrification is estimated to be US$ 2.54 million. Total investment for the combined on-grid and off-grid electrification is US$73.9 million. Covered conductors are to be used in protected areas (PAs) in order to reduce the width of the right-of-way that needs to be cleared. The length of the distribution lines in the PAs is approximately 286 km, which is equivalent to 12.3% of the total line length. The additional cost of incorporating of this environmental protection measure into the master plan is US$0.6 million.

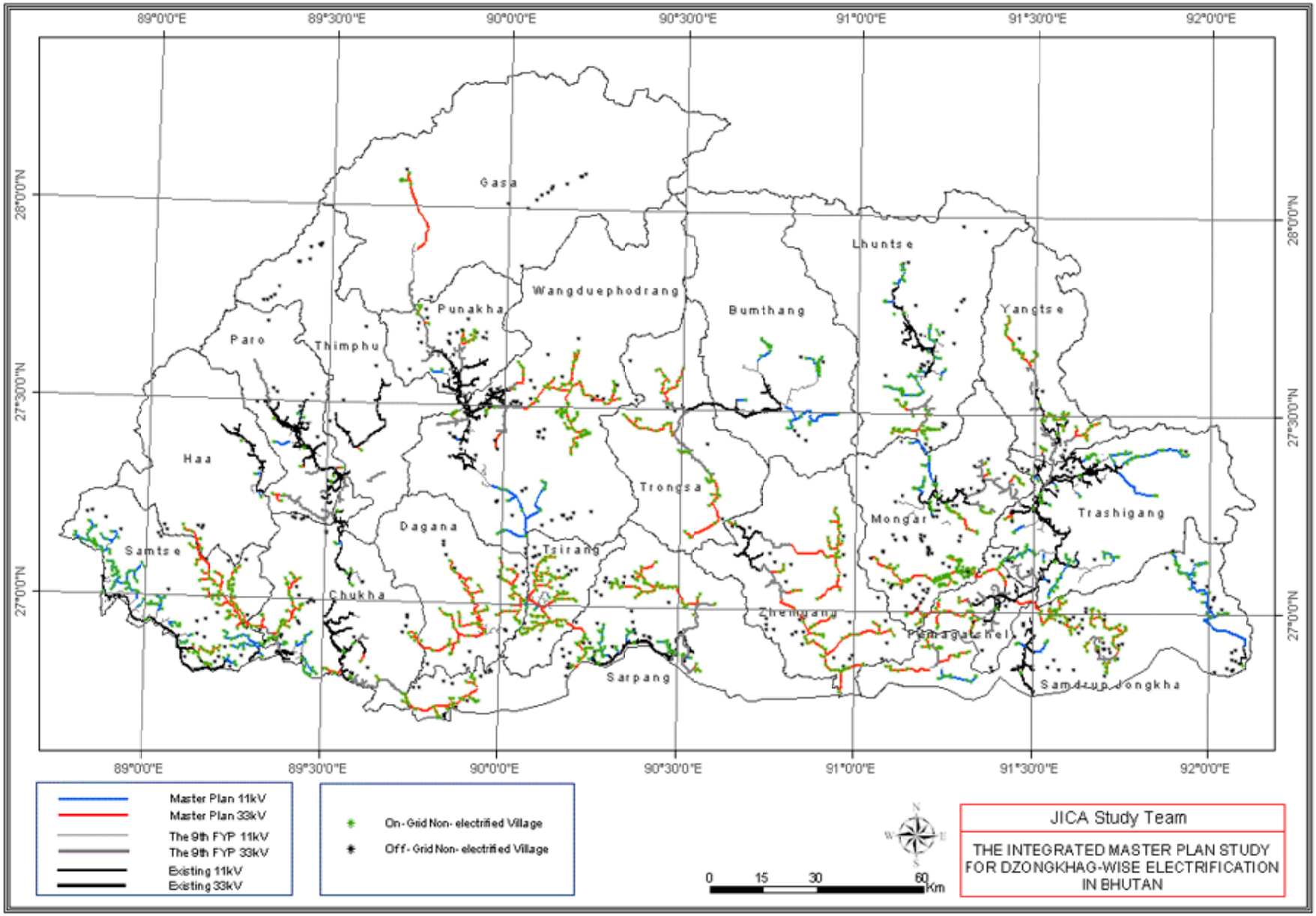
(2) Option Studies

Option-1, the electrification of non-electrified villages by all on-grid connection, was studied to compare the cost with Base Case. For Option-1, the total investment required for electrification was calculated to be US$91.4 million when all households are connected by on-grid extension. The difference between the cost of Option-1 and the Base Case is US$17.4 million. This amount represents the savings attributed to on/off-grid separation, as is done in the Base Case.

A large scale solar home system (SHS) with solar panels having the capacity of 550 Wp was defined for Option-2. This system is capable of providing power to meet the needs of both lighting and cooking. Option-2 is examined in order to compare the grid and a PV system which provides almost grid-equivalent level of utility. However, there are still some limitations in the use of electrical appliances. In terms of household connection, 99.1% of households, i.e. 43,803, out of 44,218 would find grid connection more beneficial than having a large solar home system. The investment cost of Option-2 is US$88.1 million.

Option-3 (micro-hydropower) comprises 39 proposed mini/micro hydropower (MHP) schemes in the off-grid electrification plan. This option was prepared as a desktop study and an economic evaluation was carried out. The results of economic evaluation of benefit-costs (B-C) for the year 2020 show that 5 MHP schemes were evaluated as being more economically feasible than on-grid electrification. These MHP schemes are: i) Lingshi (Thimphu), ii) Jangothang (Thimphu), iii) Laya (Gasa), iv) Sengor (Mongar) and v) Khelphu (Trashigang)

This result was concluded at the desktop study level. Therefore, more detailed field surveys will be required in the future. Shingkhar-Lauri (Samdrup Jongkhar) should also be considered as a site for a MHP because there is no other on-grid power, except for power supplied from India.



Prepared by JICA Study Team

Figure-3 On/Off Grid Villages and Grid Extension in Base Case

(3) Overall Electrification Project Cost

Total project cost was estimated by summarizing the distribution line cost, off-grid solar home system cost, and information and communication equipment cost as a sub-total. The total estimated cost includes the cost of 7% of the sub-total for foreign consultancy services and 2% of sub-total for training and capacity building. In addition, 3% of equipment, transportation, and installation costs are included as administration cost for both the distribution facility and information and communication facility. The total project cost was estimated to be US$86.6 million as is shown in **Table-4**.

Table-4 Total Project Cost Estimation

Items	Amount (1,000 Nu.)	Amount (US$)
Distribution facility	3,211,010	71,355,785
Information and communication facility	242,762	5,394,720
Off-grid facility	114,407	2,542,375
Sub-total	*3,568,180*	*79,292,879*
Consultancy service	255,000	5,666,667
Training and capacity building	71,364	1,585,858
TOTAL	**3,894,543**	**86,545,404**

Prepared by JICA Study Team

(4) Effect on Poverty Reduction

Improving the well-being of the poor is one of chief goals in development. This is particularly so in the Bhutanese national policy context. The distribution analysis undertaken here follows a standard procedure adopted by the ADB. The first step in this analysis is to identify the key players for rural electrification. The second step is to allocate the financial net costs and also economic net benefits and costs to the identified players. The final step is to estimate the proportion of the poor in terms of costs and benefits and then derive a ratio called “Poverty Reduction Impact Ratio”, in order to estimate the net impact of the project to the poor. The poverty impact ratio is derived by dividing the total net benefits accruing to the poor by the total economic benefits generated by the entire project.

The estimated poverty impact ratio is 54% in this master plan. This implies that the poor will receive 54% of the net benefits created by the project.

PART-C MASTER PLAN AND IMPLEMENTATION STRATEGY

15. ON-GRID RURAL ELECTRIFICATION MASTER PLAN BASED ON ECONOMIC EVALUATION

(1) On-grid Electrification Plan by Phase

In Bhutan, a Five Year Plan (FYP) is used for national development planning. The rural electrification project will be implemented in three (3) phases within the following FYP's:

- Phase-1: 10th FYP (2007-2012)
- Phase-2: 11th FYP (2012-2017)
- Phase-3: 12th FYP (2017-2020, the target year for achieving 100% electrification)

The implementation phase in which feeders for a particular distribution line will be expanded needs to be determined. At first, the priority of each feeder and phase of expansion is determined, based on the genuine economic evaluations. After this, a phase-wise electrification plan is prepared. As one indication of a feasibility of a feeder, if a feeder has an EIRR of 12% or more, it is evaluated as being feasible. .

(2) On-grid Electrification Plan of Phase-1 (2007-2012)

10th FYP is defined as the Phase-1 trunk feeder construction period. There are 209 trunk feeders in total. For feeders that have an EIRR greater than 12%, progressively move down the list with sorted feeders by EIRR order, until the accumulated number of households in 2007 reached the target number of 20,000 for Phase-1.

125 trunk feeders were allocated for Phase-1 construction. Based on economic evaluation, the total investment required for the Phase-1 trunk feeders is US$47.3 million. The total line distance is 1,431 km. The number of on-grid electrified households is 20,654. The highest EIRR among the Phase-1 trunk feeders is 57.7%, which is for MPF11F1-7, in Lhuntse Dzongkhag. The lowest EIRR is 12.4%, which is for MPT33F2-6, in Zhemgang Dzongkhag . All the Phase-1 trunk feeders have an EIRR of greater than 12%.

(3) On-grid Electrification Plan for Phase-2 (2012-2017)

Phase-2 is for the 11th FYP. The remaining 84 trunk feeders (out of a total of 209 feeders) are planned to be constructed in Phase-2. Therefore, on-grid electrification will be accomplished by the end of Phase-2.

In Phase-2, the total required investment will be US$24.0 million, the line length is 891 km, and the number of on-grid electrified households is 8,687 as of the year 2007. The EIRR's for the Phase-2 trunk feeders are comparatively lower than in Phase-1 because the higher EIRR feeders are already allocated to Phase-1. The highest Phase-2 ERR is 21.4%, which is for MPB33F2-7 in Chukha Dzongkhag. The lowest EIRR is 6.8%, for MPL33F2-12 in Samtse Dzongkhag. In Phase-2, there are 48 feeders that have EIRR's lower than 12%.

16. OPTIMIZED DZONGKHAG-WISE RURAL ELECTRIFICATION MASTER PLAN − THE RESULT OF THE MASTER PLAN -

(1) Method for Developing the Optimized Phase Development Plan

After determining the phase in which feeders will be implemented by using a genuine economic evaluation, it was found that there was a significant difference between the percentage of on-grid households in each Dzongkhag that would be electrified by the end of 10th FYP. For instance, Dzongkhags with larger populations tended to have a relatively high electrification percentage at the end of 10th FYP. This is partly because larger populations bring higher benefits, which makes the feeder EIRR higher, so feeders with larger numbers of households were included in 10th FYP. In addition, under the current electrification program, some Dzongkhags will already have a high on-grid electrification percentage by the end of 9th FYP. However, some of the other Dzongkhags will still have a lower electrification percentage, even at the end of 10th FYP. The RGoB regards equal rural development as the most important policy. For rural electrification, it is the national policy to prepare the plan so that the electrified percentage of every Dzongkhag will become approximately equal at the end of 10th FYP.

Thus, the implementation plan that was described in Chapter 15 was modified according to the above policy, and an optimized on-grid phase development plan was prepared. This chapter describes the optimized master plan after the modification. It also explains the modification process. Here, factors relating to consistency with other development sectors, as well as the distance of the feeders from existing roads were considered. Furthermore, power flow analysis was performed for the optimized on-grid system and issues relating to the optimized distribution system were identified. The required countermeasures were presented.

In addition to the above, an off-grid electrification plan was also prepared. The final on-grid and off-grid electrification plans have been formulated to optimize the rural electrification master plan. These optimized plans comprise the final output of the master plan study. The economic evaluations for the optimized on-grid and off-grid plans were explained, and finally the optimized Dzongkhag-wise electrification plan was presented.

(2) Optimized On-grid Phase-1 Plan (10th FYP)

Out of 213 feeders, 130 feeders will be implemented in Phase-1. The number of households that will be connected to these feeders is forecast to be 21,519 in 2007. This number includes 513 households connected to existing lines from the Dagana small hydropower, of which 6.6 kV lines need to be replaced. Therefore, the actual number of non-electrified households in the master plan target that will be connected to an electricity supply for the first time is 21,006.

The total line length for the optimized 10th FYP electrification is 1,580 km and the investment cost is US$ 49.2 million.

(3) Optimized On-grid Phase-2 Plan (11th FYP)

In Phase-2, which corresponds to 11th FYP, construction of the remaining 83 out of 213 feeders will occur. The on-grid electrification plan will be completed in Phase-2 without

requiring Phase-3. Therefore, before the target year 2020, 100% electrification will be achieved by 2017. The number of electrified households forecast for 2007 is 7,819. The total Phase-2 line length is 742 km and the total cost for the on-grid electrification in Phase-2 is US$22.1 million.

Figure-4 below shows the distribution line extensions at the end of Phase-2.

(4) Off-grid Electrification Plan

The total number of non-electrified households in Bhutan is forecast to be 44,218 in 2020. This is the target of this master plan. The off-grid electrified villages are forecast to be 3,918 in 2007 and 5,133 in 2020.

Here, an off-grid system basically represents a solar home system. Mini/micro hydropower for villages with a high power source potential are defined as an optional implementation plan only when grants from donors can be secured. Accordingly, in the master plan, project cost calculations and economic evaluations apply to on-grid electrification by distribution line extensions and off-grid electrification by solar home systems. Project costs for mini/micro hydropower are not included in the master plan implementation cost.

According to DOE policy, the target off-grid electrification household number was planned to be 2,000 for 10th FYP. Around 1,900 un-electrified households (projected in 2007) were planed to be electrified in 11th FYP.

(5) Economic Evaluation of the Optimized Rural Electrification Program

This section shows the overall economic viability of the optimized rural electrification program by phase. **Table-5** shows the results of economic evaluations of on-grid electrification for each phase. 10th FYP (2007- 2012) requires expenditure of a total of US$49.2 million (2,210 million Nu.) with an EIRR of 15%. 11th FYP (2012-2017) requires expenditure of a total of US$ 21.1 million (956 million Nu.) with an EIRR of 13%. The average spending per year is equal to US$7.0 million. Table-16.6.2 shows the cash flow tables for each phase of development. The overall return on investment shows a healthy investment viability of above 12%.

Table-5 Summary of Optimized Grid Extension Economic Analysis

	Unit	Phase-1	Phase-2
		2007-2012	2012-2017
Investment	Nu. million	2,215	996
	US$ million	49.2	22.1
Distance	km	1,580	742
Household	Nos	21,519	7,819
EIRR	%	14.6%	12.8%

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The small scale system has an IRR of 25%, while the larger system of 550 Wp shows a negative investment return of -9%.

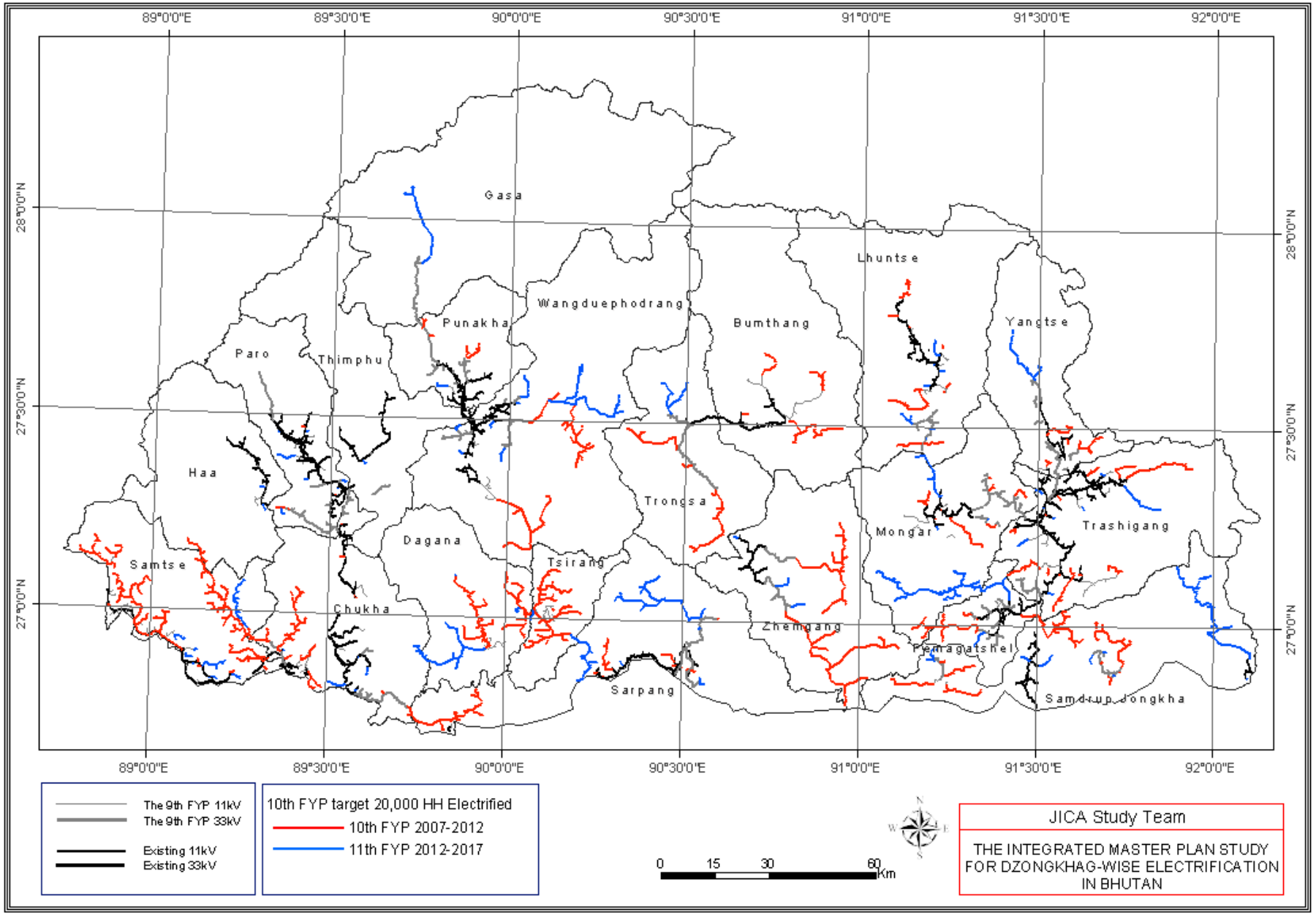

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Figure-4 On-grid Rural Electrification Plan by Phase

(6) Electrification Level

Table-6 shows the accumulated number of electrification households and electrification percentages by Dzonghag.

The on-grid electrification percentage forecast was 55.2% in 2007, at the end of 9th FYP. It will be 84.5% at the end of 10th FYP, increase to 94.7% at the end of 11th FYP in the whole country. The target of 100% rural electrification will be achieved by the end of 11th FYP in this master plan. Approximately 95%[12] of rural households will be connected to the grid (on-grid) and remaining 5% will be electrified by off-grid means.

Table-6 Rural Electrification Percentage by Dzongkhags

Dzongkhag	Target nos of Electrifi-cation	At the end of 9th FYP		At the End of 10th FYP			At the End of 11th FYP			
		On Grid Electrified Households	% On-grid Electrified	On Grid Electrified Households	off + non-electrified Households	% On-grid Electrified	On Grid Electrified Households	Off-grid House-holds	% On-grid Electri-fied	Total % Eletrified
Bumthang	2,012	1,518	75.4%	1,993	19	99.1%	1,993	19	99.1%	100%
Chukha	4,550	2,565	56.4%	3,987	563	87.6%	4,266	284	93.8%	100%
Dagana	2,983	1,019	34.2%	2,750	233	92.2%	2,783	200	93.3%	100%
Gasa	569	207	36.4%	207	362	36.4%	391	178	68.7%	100%
Haa	1,203	926	77.0%	1,108	95	92.1%	1,134	69	94.3%	100%
Lhuntse	2,643	1,166	44.1%	1,987	656	75.2%	2,349	294	88.9%	100%
Mongar	5,851	2,986	51.0%	4,043	1,808	69.1%	5,353	498	91.5%	100%
Paro	4,387	4,213	96.0%	4,270	117	97.3%	4,317	70	98.4%	100%
Pemagatshel	2,772	2,129	76.8%	2,599	173	93.8%	2,724	48	98.3%	100%
Punakha	2,414	2,139	88.6%	2,306	108	95.5%	2,321	93	96.1%	100%
Samdrup Jongkhar	5,574	1,737	31.2%	3,940	1,634	70.7%	5,173	401	92.8%	100%
Samtse	7,879	3,114	39.5%	6,772	1,107	85.9%	7,624	255	96.8%	100%
Sarpang	5,093	2,100	41.2%	3,485	1,608	68.4%	4,708	385	92.4%	100%
Thimphu	1,933	1,798	93.0%	1,798	135	93.0%	1,812	121	93.7%	100%
Trashigang	8,752	6,546	74.8%	8,152	600	93.1%	8,596	156	98.2%	100%
TrashiYangtse	3,102	1,840	59.3%	2,714	388	87.5%	3,067	35	98.9%	100%
Trongsa	1,729	768	44.4%	1,474	255	85.3%	1,697	32	98.1%	100%
Tsirang	3,406	812	23.8%	3,235	171	95.0%	3,265	141	95.9%	100%
Wangdue phodrang	4,225	2,388	56.5%	3,325	900	78.7%	3,851	374	91.1%	100%
Zhemgang	2,322	565	24.3%	1,901	421	81.9%	2,057	265	88.6%	100%
TOTAL	**73,399**	**40,536**	**55.2%**	**62,046**	**11,353**	**84.5%**	**69,481**	**3,918**	**94.7%**	**100%**

All households were forecast number of the year 2007 to calculate electrified percentage, since existing electrified household in 9th fYP was only available in 2007.

* Dagana includes 396 households connected to existing line to be replaced.

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ICA Study Team

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17. STRATEGIC ENVIRONMENTAL ASSESSMENT (SEA)

(1) Intention of Applying Strategic Environmental Assessment

RGoB has set a significant electrification target, which is "100% rural electrification by the year 2020". On the other hand, RGoB aims at coexistence with the environment and sustainable development, as well as preservation of 60% forest coverage for the country. In the environmental legislation, the regulation on Strategic Environmental Assessment (SEA) in 2002 stipulates that SEA is required in preparation of national master plans. There has not been any case so far where SEA has been undertaken. However, in accordance with the SEA

[12] The number includes existing and 9th FYP on-grid rural electrification household, whereas 88.4% on-grid electrification percentage descript in Chapter 14 is the number for only master plan target households.

regulations, the concept of SEA was applied in the preparation of the Master Plan for rural electrification. The following definition is used for this undertaking:

- Environmental consideration in the master plan stage enabling avoidance of significant impacts that may be caused by implementation of the proposed project.

The matters shown below were also taken into account. These things are to be achieved by the application of the SEA concept to preparation of the master plan considering the existing SEA Regulation in Bhutan as well as the JICA Guidelines for Environmental and Social Considerations:

- To enhance and apply the concept of sustainability in governmental decision making;
- To avoid significant and cumulative impacts on the environment through environmental consideration in the early stages of a project; and
- To support and strengthen EIA in the implementation phase of projects.

(2) Mitigation Measures and Analysis of Environmental Impact

The following two policies were adopted when considering environmental and social impacts, as well as the mitigation of environmental impacts:

- Prioritization of the protected area and biological corridor in environmental Consideration; and
- Consideration of cumulative impacts on the environment

"Biological corridors" are established areas that enable wild animals to move from one protected area to another.

Cumulative environmental impact is caused by environmental impacts of several large-scale development activities, and it can be reduced by coordination with other sectors. In the master planning work done for the Study, road projects were considered.

■ Mitigation Measures in the Preparation of the Master Plan

The measures shown below were adopted for environmental mitigation in the master plan:

- Locating distribution lines along roads;
- Avoiding protected areas and corridors as much as possible; and
- Application of covered conductors for grid extensions that must be located in protected areas to allow a narrower width of vegetation to be cleared for the right-of-way.

■ Consideration of the Cost of Environmental Conservation

In order to take environmental aspects into account in the economic evaluation, a part of the internal cost required for environmental mitigation measures was added to the project cost. Namely, increased costs due to the use of covered conductors for distribution lines in environmentally prioritized areas were added to the project cost. On the other hand, costs related to external environmental affects, such as the value of biodiversity and the impact on communities of construction work, etc. were not included. These external effects can not be traded in actual markets. Therefore, these costs were not included in the economic

evaluation because conversion of such costs into a monetary value contains a lot of uncertainty.

The internalization of environmental mitigation costs brought about a reduction in distance of the on-grid extensions proposed in the master plan. This resulted from weighting the environmental consideration in the planning process. Before implementation of construction work, especially in the environmentally prioritized areas, the actual environmental situation should be checked. This will require a detailed environmental examination to be conducted.

(3) Publicity of the Master Plan Study

In the course of the Study, three workshops were held for discussing the project and for giving information about the project to stakeholders. Environmental consideration, as well as environmental examination in rural electrification, was one of the items presented and discussed in all three workshops.

(4) Environmental Effect Mitigation Measures in the Implementation of Project

In the implementation stage, detailed circumstances will become clearer. Therefore, environmental effect mitigation measures will need to be considered again according to the actual situations that are encountered.

In preparation of the master plan, coordination of power sector and road sector with existing and planned roads information was supposed to enable smooth implementation of the rural electrification project. It is desirable to share and utilize the accumulated data and information with not only the road sector, but also other sectors. This will encourage the effective conduct of SEA for road and city development projects, as well as for EIA of each project.

(5) Preparation of a Draft TOR for EIA

The EA Act (2000) stipulates that if a project is evaluated as giving rise to significant environmental impacts according to the information described in the application for environmental clearance, the proponent would have to conduct an EIA. The proponent would have to submit a Terms of Reference (TOR) for the EIA to NEC before implementation. The TOR should include methods for site surveys for various environmental features, prediction and evaluation of environmental impact, etc. The TOR should be proposed before conducting an EIA. However, there have not been any cases so far of an EIA being done based on EA Act (2000) at present.

Information about the preparation of a draft TOR for the EIA was provided in the master plan report. It is intended that this information be used when making the actual TOR in the master plan project implementation phase. The draft TOR can be referred to when it is necessary to conduct an EIA in the future.

18. EXPANSION PLAN FOR THE INFORMATION AND COMMUNICATIONS NETWORK

(1) Expansion Plan for the Information and Communications Network

In this master plan, the information and communications network was planned to be expanded by installing fiber optic cables along with power lines that are constructed for the electricity distribution network.

Fiber optic cable on existing and ADB/RE-3 distribution lines must also be considered when constructing a nationwide network. Therefore, the full project cost estimation includes additional information and communication facilities on existing or ADB/RE3 distribution lines.

(2) Demand and Benefit for Expansion of the Information and Communications Network

Demands on the fiber optic network that can be expected are summarized in **Table-7** below.

Table-7 Fiber Optic Network Demand and Benefit

Public Services by the Government	Efficiency of Public Services and Promotion of the RGoB Policy of Decentralization. Better Service for People Better Database Systems for Government Ministries and Agencies
Communications Service	Stability of a Backbone Network with Large Capacity Rural Network with a Large Capacity Ready for IP-based Networks Low Maintenance Cost and Long Life Span More Profit/Business Chance for BTL
Broadcasting Service	Expansion of the Service Area Better Program Production Real Time Program Delivery
Education Service	Better Quality of Education Services in Rural Areas Training Opportunities for Teachers in Rural Areas by Distance Education Possibility of Distance Education and ICT Education for Students
Health Services	Better Communications Facility Videophone Service for Better Consultation Internet to Get Necessary/Useful/Important Information.

Prepared by JICA Study Team

(3) Cost of the Expansion Plan for the Information and Communications Network

The overall cost estimate for the information and communications network project is shown in **Table-8** below. The total project cost is estimated at US$5.4 million.

Table-8 Information and Communications Network Overall Cost Estimate

Item	Quantity	Unit Price	Subtotal	Note
SSF 8 Core Cable	1,015 km	US$2,160/km	US$1,974,456	Installed along with the new electricity distribution line of the master plan.
	1,224 km	US$2,160/km	US$2,380,968	Installed on existing / ADB/RE-3 power lines.
OTE	40	US$18,000/Unit	US$648,000	
SPTE	193	US$1,920/Unit	US$333,696	
Repeater	80	US$800/Unit	US$57,600	
Total			US$5,394,720	

Note: Unit prices mentioned above are for 10th FYP only, and do not include a price decrease in 11th and 12th FYPs. Therefore, the quantity multiplied by unit price is not equal to the subtotal.
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(4) Economic Evaluation of the Information and Communications Network

From a viewpoint of security of the nation, the information and communications system has a From the viewpoint of security of the nation, the information and communications system has a vital value beyond mere economics. However, the redundancy of the proposed network limits the economic evaluation within the narrowly-defined benefit of cost-saving and demands for better and added functionalities. The results of the economic analysis show that the expected return on investment will be 1.8% for 10th FYP. However, the return on investment improves for the later phases: 6.2% for 11th FYP and 24.0% for 12th FYP. This indicates that delayed implementation will improve the economic viability of the project. Sensitivity analyses show that for the 10th FYP, the return on investment drops to 1.6% for a 20% investment cost increase scenario and to -0.3 % in the case of 20% demand reduction scenario, when using factors for a cost escalation (20% up) and target demand reduction (20% down). For the case of 100% Internet demand capture, the EIRR increases to 9.0 %. However, in the case of 0% realization, the EIRR drops to -2.5%.

The use of new data communication systems depends on many additional factors. These need to be developed beyond construction of the telecommunications infrastructure. For example, software, client-level investment for PC's and other digital equipment, and the digital and audio-visual content that is to be delivered. Another critical element in rural areas is lack of people who are proficient in using these new technologies. Among all factors, the most critical is the institutional resolve to bring new services on line, either by the private or public sector, for the realization of benefits. Whether the initiatives and investments will be undertaken in a timely manner to justify the investment in a small country like Bhutan itself is a matter for speculation. The broader societal demand should be investigated further before the implementation.

19. IMPLEMENTATION PLAN

(1) Project Package

In order to secure a conclusive realization of the master plan, it is effective to split the total master plan into appropriate project packages.

In particular eight (8) packages are proposed. This allows various donors to focus on specific components of the overall project, and carry them out easily.

Needless to say, at some future time RGoB will need to implement the projects and afterwards Bhutan's people will need to manage the project in a sustainable way and within Bhutan's own budget. Until that time, the packages would be useful for both Bhutan and donors; Bhutan needs some donors to assist with implementation of the projects and donors are looking for suitable projects that meet their budget and assistance policies.

(2) Funding Plan

■ On-grid Electrification

The funding source for the on-grid electrification and distribution extension project will be JBIC and ADB.

RGoB officially submitted a loan request to the Embassy of Japan on May 24, 2005. In reply to the request, JBIC will conduct a Special Assistance for Project Formation (SAPROF) study from November 2005. It is expected that the loan will be pledged soon after the SAPROF study is completed.

ADB has been major financer for the rural electrification in 7th, 8th and 9th FYPs, and has the intension to continue offering loans for rural electrification in 10th FYP.

■ Off-grid Electrification

As a result of the master plan studies described earlier in the Chapters 14 and 16, the scale of off-grid electrification has been determined to be approximately 12%, or 5,133 households. RGoB plans to electrify 2,000 off-grid households in 10th FYP. To finance this off-grid electrification, RGoB has a policy that Bhutan will not apply for a loan to finance the off-grid electrification, but will make use of grant aid from foreign donors or provide some assistance from the Bhutan government's budget.

In order to support the off-grid electrification program, it is proposed to set up and prepare a framework for an Off-grid Rural Electrification Fund (OFF-REF) to support installation, operation and maintenance, capacity building, monitoring, and promotion by the private sector.

(3) Institutional Framework for the Rural Electrification Project Implementation

■ On-grid Electrification

Although improvement of BPC's work efficiency is required, the current rural electrification implementation structure and functions DOE and BPC will be successful. The following DOE strategies for the power sector during 9th FYP are expected to be realized:

- Human Resources Development (HRD) through a skills development and training program for strengthening the institutional capacity for various sectors;
- Examination of the possibility of forming a centralized maintenance section (Begana and its small transformer manufacturing unit are to be privatized);
- Study of the possibility of providing power distribution services by community electricians (e.g. City Corporations to look after all utility services in a town) and private sector participation in billing and payment collection, depending upon the feasibility;
- Entrepreneurial skills development and training of community electricians, wiremen and linesmen for self-employment in the electrified areas for internal wiring, repair and line construction and maintenance contracts; and
- Skills development and training of private electricians, wiremen and linesmen under an ADB-TA scheme.

■ Off-grid Electrification

The following policies were proposed to prepare the institutional organization for the implementation, operation, and maintenance of off-grid electrification with solar home systems:

- To introduce a subsidy. At the same time, to enhance the user's sense of ownership. It requires the users to share some of the cost burden for installation, operation and maintenance;
- To increase efficiency, equipment procurement is proposed to be done by bulk purchase by the government, and the equipment is proposed to be rented to users. The user's share of the cost would be collected as part of the installation expense; and
- Installation, operation and maintenance are to be carried out by the private sector. Efficiency will be increased by establishing a private/public partnership.

The roles of the implementation stakeholders, Renewable Energy Division (DOE-RED), development and finance organizations, the private sector through rural electrification service companies ((RESCO), and users were proposed on the master plan.

(4) Implementation Schedule

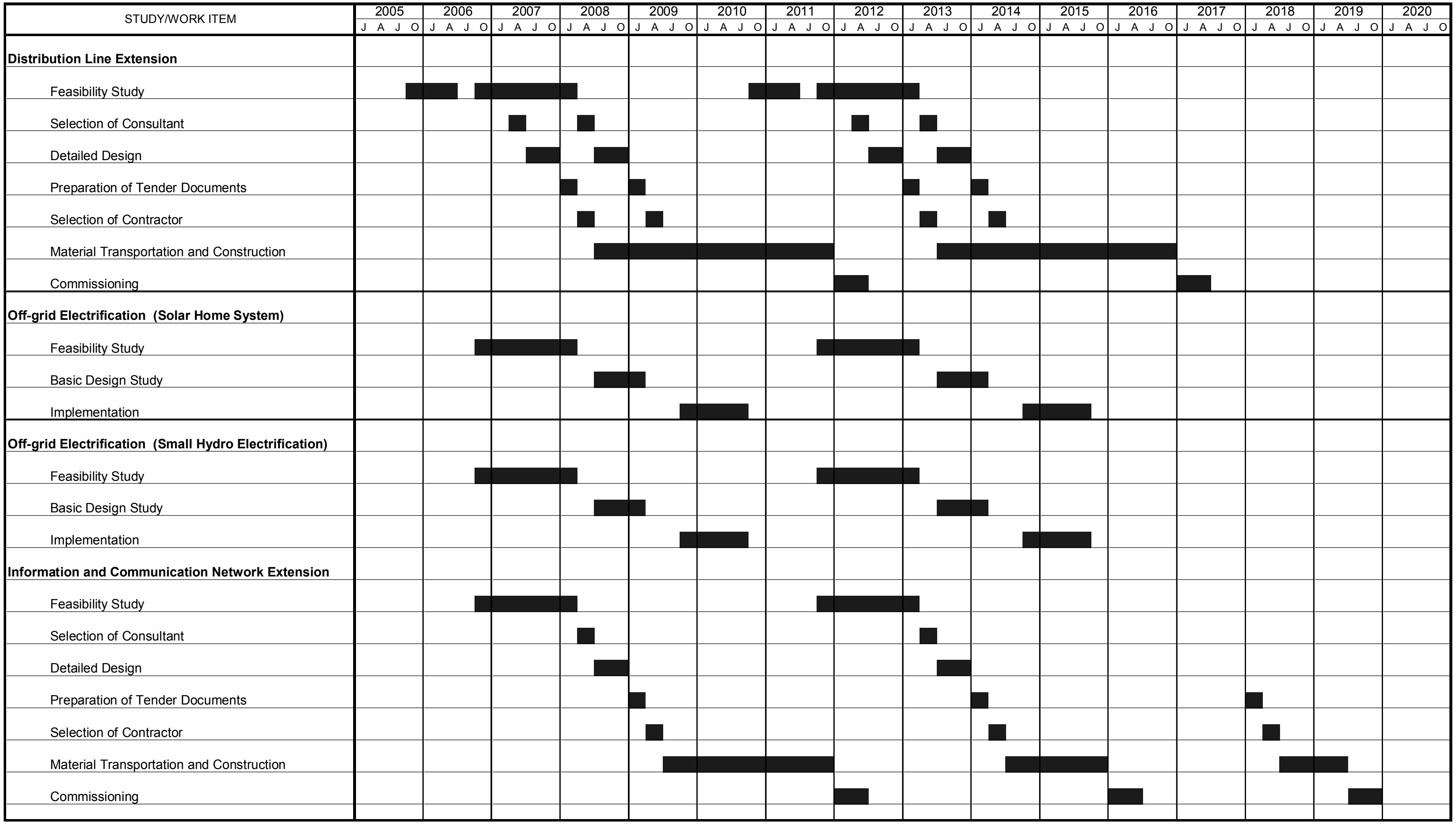
The proposed implementation schedule is shown in **Table-9**.

(5) Implementation Plan for 10th Five Year Plan

The implementation period of the master plan is from the middle of July 2007 to the middle of 2020; the first phase of the implementation of the master plan – 10th FYP – starts at the same time and ends in the middle of July, 2012.

Figure-5 below shows a sample scenario in 10th FYP for on-grid electrification project which is the major component of the master plan.

Table-9 Project Implementation Schedule



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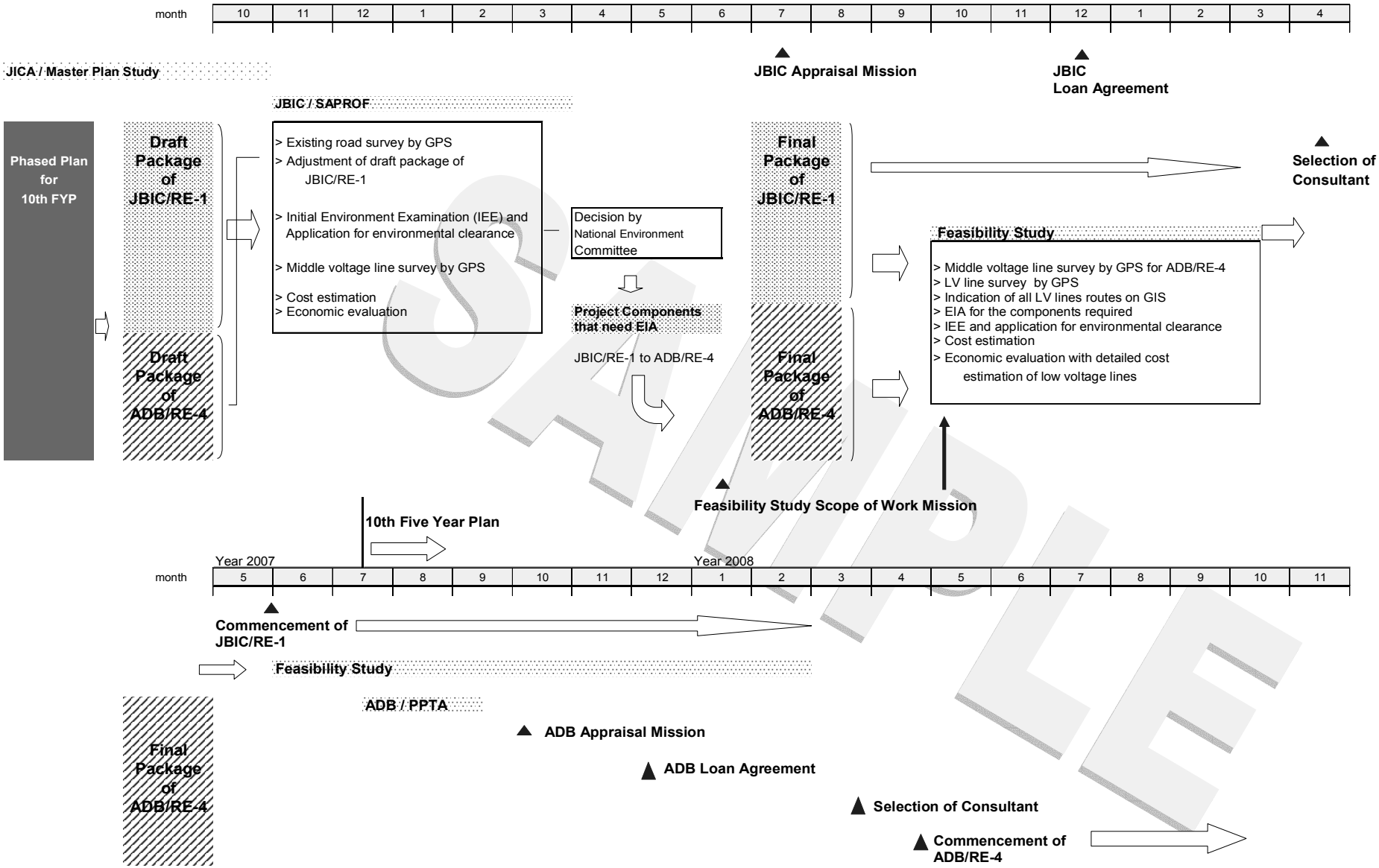


Note: The scenario is prepared as sample by Study Team, there is no any commitment for the studies stated above to be conducted.

Prepared by JICA study Team

Figure-5 Sample Scenario for On-grid Electrification in 10th Five Year Plan

20. OPERATION AND MAINTENANCE PLAN

(1) On-grid Institutional Plans for Operation and Maintenance

A transparent accounting system and increased efficiency of construction and operation of the rural power distribution system is essential to allow continuation of a rural power distribution service that is not economically feasible. Thus, establishment of new companies, tentatively called "Rural Power Supply Holding Company" and "Village Power Distribution Company" are proposed in the master plan.

■ Rural Power Supply Holding Company

There is a general consensus that the government will need to subsidize rural electrification and electricity distribution. There is a concern that excess subsidization will provide little incentive to improve efficiency, while an inadequate subsidy could lead to poor maintenance and poor quality of service, and at worst, to disinvestment. Therefore, accurate accounting information is necessary to determine the level of subsidy and tariff levels.

Separation of the business function for supplying power to rural areas from BPC, which supplies power nationwide, is the most effective method for making the accounting process related to rural electrification transparent. However, inefficiencies due to duplication of organizational structures should be avoided. Therefore, the new organization will not have any technical staff, and only deal with financial matters.

It is recommended that a small-size holding company be established. This holding company will owns all the facilities related to rural power distribution, but will only deal with financial aspects of the business. A holding company, staffed by capable financial experts, can manage the assets and instill management efficiency for the construction and operation of the rural power distribution network.

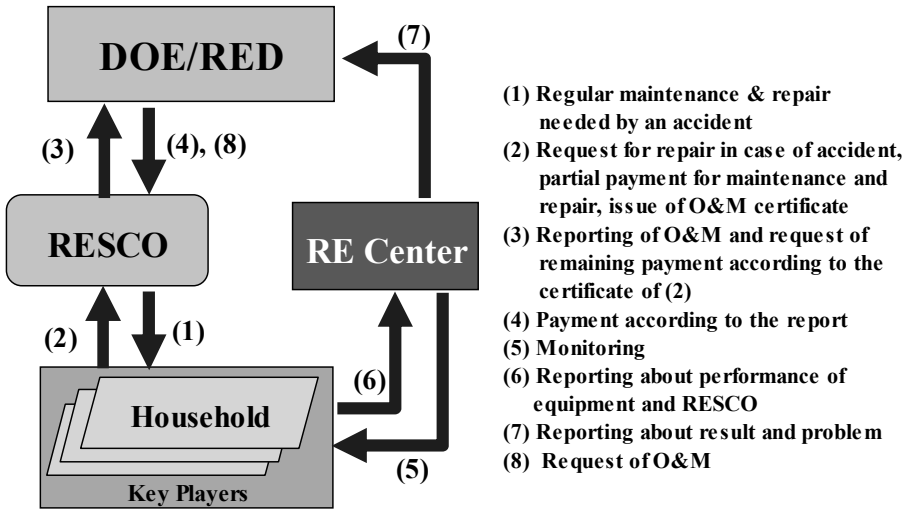
■ Village Power Distribution Company

One way to reduce the cost of meter reading and bill collection is to allocate this function to the village level. Here, "village level" means a cluster of villages in one locality, so that economic efficiency in operations will be enhanced. There is no doubt that the cost of administration will be reduced. However, the system should be structured in such a way that the local management is fully aware of the risks and consequences of poor accounting and lack of technical skill enhancement.

Village Power Distribution Companies (VPDC's) will assume the responsibility for LV lines after the MV/LV transformers. The VPDCs' responsibility includes meter reading, billing, LV line maintenance and maintenance of internal wiring in houses. The technical capacity of the operators needs to be improved with the assistance of BPC and DOE, to cope with the increased responsibilities. An insurance system for repair and maintenance that is pooled and managed by BPC or the holding company is envisaged. This insurance system will provide cushioning for unexpected events and the consequent need for spare parts and replacement of major components,

(2) Off-grid Institutional Plans for Operation and Maintenance

It is realistic to contract out the operation and maintenance work for the off-grid electrified households, which are based on solar home systems, to the private sector in Bhutan. The institutional framework for the off-grid operation and maintenance system is shown in **Figure-6** below.



Flow of O&M and Monitoring

O&M and Monitoring

The RESCO carries out regular maintenance for users and replacement of equipment damaged by accident. According to operation and maintenance completion, users pay their share of the cost to the RESCO and the user issues an Operation and Maintenance Completion Certificate.(1), (2)

The RESCO requests payment from RED for the difference between the certificate amount and the actual cost. RED pays the RESCO according to this request.(3), (4)

The RE Center regularly monitors households selected at random, according to the RED monitoring plan, and reports to RED. RED orders the RESCO to do remedial work when problems are found in their contracted work.(5)~(8)

Prepared by JICA Study Team

Figure-6 Framework of O&M and Monitoring of Off-grid Electrification with Solar SHS

The framework for human resources development associated with rural electrification is proposed. The framework is made up of the following two components:

- Establishment of Rural Electrification Center (RE Center) as a training and maintenance facility; and
- Training for management staff and for operation and maintenance staff.

The function of the center is to provide capacity building of staff involved in operation and maintenance of rural electrification. Base stations will be located in Thimphu for the western region, Wangdue Phodrang for the central region, and Mongar for the eastern region.

(3) Possibility for Applying Demand Side Management and Its Position in the Master Plan

Demand Side Management (DSM) is the general concept of improving the total efficiency of the energy supply system by introducing energy-saving appliances and/or leveling the load fluctuation etc., on the demand side (i.e. consumers). It is possible to apply this concept to the master plan for rural electrification in Bhutan.

The recommended way for practical DSM to be applied particularly to rural electrification in Bhutan is as follows:

- Introducing LED lamps
- Hydrogen production and use on the demand side

21. CONCLUSION AND RECOMMENDATION

(1) Conclusion

The conclusion of the master plan study is shown below.

1. All the target villages of the master plan study, which are to be electrified in and after 10th FYP, i.e. from July 2007, were visited and surveyed by the local consultant recruited by Study Team. As the result of this site reconnaissance, it was confirmed that there were 1,716 non-electrified villages and 29,942 non-electrified households in those villages.
2. The location coordinates (longitude and latitude) of all the non-electrified villages were recorded by GPS. These coordinate data were transferred to a GIS data and saved. In addition, GPS was used to record the location of the existing middle voltage lines and the planned middle voltage lines to be constructed in 9th FYP. These coordinates were also transferred to the GIS. By utilizing these data, the major work of formulating the master plan was efficiently conducted via use of GIS software.
3. The demand forecast up to 2020 of all the non-electrified villages was carried out. The Study Team forecast that the number of non-electrified households would increase to 43,702 in 2020. Through this increase of household numbers and the associated increase in electricity consumption of each household, the total demand of all the non-electrified villages in 2020 was estimated to be 58.6 MW for peak demand and 9,623 MWh/month for energy consumption.
4. The Study Team forecast the future demand of the area that is already electrified. The national demand of both non-electrified villages and the existing electrified area in 2020 were forecast at 442.7 MW for peak demand and 182 GWh/month for energy consumption. With regard to the power source side, there seems to be no problem because the total generating capacity of Bhutan will increase to around 1,450 MW after the Tala hydropower station (1,020 MW capacity) starts its operation in 2006.
5. The electrification method for non-electrified villages was decided one by one through doing economically rational analysis to compare on-grid electrification by distribution extension and off-grid electrification by a solar home system (SHS).
6. As the result of the above on/off-grid analysis, it was determined that in 2020, 73.8% of non-electrified villages, which comes to 88.4% of non-electrified households, would be electrified by on-grid, and the remaining villages and the households would have off-grid electrification. The total length of the required distribution lines was estimated to be 2,321 km and the construction cost of these lines was estimated to be US$71.35 million. The cost of solar home systems for off-grid electrification was estimated to be US$2.54 million.
7. In the master plan, 100% of electrification is planned to be accomplished by the end of 2017, which is the last year of the 11th FYP. The master plan was also summarized on a Dzongkhag-wise basis so that the Dzongkhag people could easily refer to their own Dzongkhag electrification plan.
8. The on-grid electrification plan for the 10th FYP envisages that 858 villages and the corresponding 21,519 households (year 2007 basis) will be electrified. The investment

cost for the 10th FYP work of on-grid is estimated to be US$49.2 million. By the end of the 11th FYP, 410 villages and the corresponding 7,819 households (year 2007 basis) are planned to be electrified. The investment cost for the 11th FYP work is estimated to be US$22.1 million.

9. The study team examined the possibility of utilizing micro hydro power (MHP) for off-grid village electrification. An economic evaluation and comparison with on-grid electrification was conducted for 39 MHP schemes at the desktop study level. The results of the analysis showed that 5 of the proposed MHP schemes (Lingshi and Jangothang in Thimphu Dzongkhag, Laya in Gasa Dzongkhag, Sengor in Mongar Dzongkhag, and Khelphu in Trashigang Dzongkhag) were evaluated as being economically more feasible than on-grid electrification. Among these 5 schemes, the Sengor MHP project is to be started in 2005 with UNDP/GEF funding support. For other 4 schemes, and some additional sites where grid extension is technically difficult or the power supply from the Indian grid is not preferred (such as Shingkhar-Lauri in Samdrup Jongkhar Dzongkhag), further detailed surveys and feasibility studies are recommended.
10. In the master plan formulation stage, the Study Team paid a lot of attention to environmental conservation, and stated necessary countermeasures and recommendations for ensuring environmental protection. Therefore, the Study Team believes that the environmental burden incurred by the implementation of electrification projects will be mitigated.
11. For the efficient rural development, the expansion of the information and communications network is planned along with the rural electrification plan. The information and communications network plan is scheduled to be implemented in three phases over five year plans 10 to 12. The EIRR of each phase of the plan was estimated to be 1.8%, 6.2% and 24.0%, respectively for the 10th, 11th, and 12th FYP. Based on this result, the Study Team considers that implementation of the project is rational.
12. Regarding the operation and maintenance of rural electrification, the Study Team proposed a financially transparent and efficient institutional setup. This will be achieved by introducing the idea of a holding company and decentralized operation systems for on-grid electrification. For off-grid electrification, the Study Team proposed cost sharing with the consumers to enhance the consumers' sense of ownership. In addition, private sector participation is suggested to undertake the operation and maintenance work in order to secure sustainability of the project.
13. Close collaboration with the Bhutanese counterparts was carried out when formulating the master plan in order to achieve effective technology transfer. By setting clear targets for the technology transfer; such as all the presentations in the workshops being carried out by the Bhutanese counterparts, efficient and high level technology transfer was achieved.

(2) Recommendation

The recommendations of the master plan study are listed below.

1. The Study Team proposes that the on-grid electrification and distribution line extension project package for the 10th FYP be implemented by loans from JBIC and ADB, respectively. JBIC had already started their SAPROF study in October 2005. In this

study, it is conceivable that the site survey of the middle voltage lines and the application of the environmental clearance will be conducted. After the SAPROF study is completed, the route decision for the low voltage lines, quantity and cost estimation, and if necessary, execution of an EIA, will remain as major works. The Study Team recommends, as one option, that all these works be conducted under technical assistance from donor agencies including JICA.

2. The master plan needs to be reviewed, if possible every year, and at least once in each of the five year plans. To allow the Bhutanese counterparts to conduct this review by itself, the Study Team made a lot of effort to carry out the required technology transfer during the master plan study. Many conditions that were used to formulate the master plan will vary as time goes on. It is recommended that the master plan be reviewed with the latest data, especially paying attention to the forecast demand and price decrease of the equipment required for solar home systems.
3. Regarding the above forecast demand, the Study Team recommends confirming whether the forecast demand was appropriate or not by making sample measurements of electricity consumption of households for various 24 hour periods.
4. As one of the alternatives for demand side management, the application of new technology, such as Hydrogen and Fuel Cell technology are worth considering in the future. Using surplus energy generated in off-peak times for electrolysis to decompose water into hydrogen and oxygen could be done. The energy could be stored as liquid hydrogen. During peak times, the chemical energy contained in the hydrogen can be converted to electrical energy by using a Fuel Cell. The hydrogen is also able to be used directly for cooking, heating, and hot-water supply by direct combustion of hydrogen-gas in a cooker/grill or burner. The hydrogen could also be used for transportation, in the form of a Fuel Cell vehicle, etc. Hydrogen technology is expected to become a measure for reducing CO2 emissions and, by reducing timber usage for cooking and heating, also for forest preservation.
5. The Study Team recommends formulating a data base for basic environmental information. At present, consolidation of the existing data about natural and social environment is not sufficient. Although a lot of studies have been conducted regarding flora and fauna, the data cannot be used easily because it is not systematically consolidated.
6. The proposed information and communication network expansion plan is included in the project to reduce the rural development costs and also make the rural development more efficient by coordinating different sectors. As the next step, it is recommended that further studies be conducted as part of the feasibility study.